NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A STUDY OF ANTARCTIC REMOTE SITE
AUTOMATIC WEATHER STATION DATA (1980-81)
FROM THE ROSS ICE SHELF AREA

by

Suzanne Plott Hervey

March 1984

Thesis Advisor: R. J. Renard

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Study of Antarctic Remote Site Automatic Weather Station Data (1980-81) from the Ross Ice Shelf Area		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; March 1984
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Suzanne Plott Hervey		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93943		12. REPORT DATE March 1984
		13. NUMBER OF PAGES 170
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Weather, Antarctica; McMurdo, Antarctica; Automatic Weather Stations, Antarctica; Ross Ice Shelf, Antarctica; Wind, Temperature, Pressure, Antarctica

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The third generation of the Antarctic remote-site Automatic Weather Stations (AWS2B) was installed at various locations during Austral summer (1979/80). The quality and quantity of surface pressure, wind (speed and direction) and temperature data show a marked improvement over that of the earlier AWS platforms (1976-80) examined by personnel at the Naval Postgraduate School, Monterey, California.

Statistical processing of data from February 1980 to December 1981 was done in order to contribute to a base climatology for AWS sites and to investigate possible operational applications of the data to the United States Antarctic mission. Comparisons were made between synoptic reports collected at McMurdo, Antarctica and the data obtained from the surrounding AWS2B stations.

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A Study of Antarctic Remote Site Automatic Weather Station Data (1980-81) from the Ross Ice Shelf Area

by

Suzanne Plott Hervey
Lieutenant, United States Navy
B.A., Ripon College, 1975

MASTER OF SCIENCE IN METEOROLOGY AND OCEANOGRAPHY

from the

NAVAL POSTGRADUATE SCHOOL
March 1984

ABSTRACT

The third generation of the Antarctic remote-site Automatic Weather Stations (AWS2B) was installed at various locations during Austral summer 1979/80. The quality and quantity of surface pressure, wind (speed and direction) and temperature data show a marked improvement over that of the earlier AWS platforms (1976-80) examined by personnel at the Naval Postgraduate School, Monterey, California. Statistical processing of data from February 1980 to December 1981 was done in order to contribute to a base climatology for AWS sites and to investigate possible operational applications of the data to the United States Antarctic mission. Comparisons were made between synoptic reports collected at McMurdo, Antarctica and the data obtained from the surrounding AWS2B stations.

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I. INTRODUCTION

The remote-site Automatic Weather Station (AWS) program for the Antarctic was initially described by Renard and Salinas (1977). This first study dealt with the installation of a prototype station (AWS-1), variously at three locations in the Antarctic from February 1975 to May 1977. A second study by Scarbro (1982) described the follow-on network of Automatic Weather Stations (AWS-2A) in the January 1979 to February 1980 time frame. Seven AWS-2A stations were deployed during that period, reporting through the Nimbus VI Random Access Measurement System (RAMS).

From its inception, the AWS program has been under the direction of its funding sponsor, the National Science Foundation (NSF). The original AWS developer, Stanford University, worked closely with NSF and the Naval Postgraduate School, Monterey, California (NPS) during the early stages of deployment. Since early 1980 when headquarters for development shifted to the University of Wisconsin (UW) an enhanced scientific/operational interest in AWS has been evidenced by ongoing research at the Universities of Wisconsin, Wyoming and Alaska; Florida State and Ohio State Universities, the Naval Postgraduate School and the Naval Support Force Antarctica.

This report will document the operation and performance of, and data collected by the AWS platforms operating during the period February 1980 through December 1981. These AWS, referred to here as AWS2B, are uniquely designed to transmit sensor data to the polar orbiting Tiros-N/NOAA-6,7 satellites via the French operated ARGOS data collection system.

II. AWS-2B PLATFORM AND INSTRUMENTATION

A. PLATFORM

The AWS-2B platform is essentially the same as the prototype AWS reported by Renard and Salinas (1977) with modifications as described by Scarbro (1982).

B. INSTRUMENTS

The instrumentation specifications are described fully by Renard and Salinas (1977). The following amplifications on temperature, pressure and wind sensors, obtained from Mr. K. Chen, Department of Meteorology, Stanford University, illustrate the ARGOS data collection system currently (i.e. February 1980 through December 1981) utilized by AWS-2B, in comparison to the RAMS data collection system used by AWS-1 and AWS-2A.

1. Temperature

Both internal and external temperatures are now measured by the platinum wire sensors which provide the necessary precision. The same Weed unit as in the prototype AWS is being used but the method of reading the resistance has been changed.

The temperature data sent back from the AWS-2B consist of a 12-bit integer whose value is eight times the actual temperature (in deg C) and offset by 100 deg C.

External and internal temperatures are taken every ten minutes (i.e. 0, -10, -20, -30, -40 min), stored in the data memory bank, and read out during each transmission.

In the actual transmission, only the latest reading is transmitted in its full twelve bits. The other four temperatures are sent back as differences and require only six bits each.

2. Pressure

The experience gained from the original AWS has resulted in the modification of pressure measurements in order to maintain an accurate time base for the pressure calculations. This is accomplished by having the AWS-2B carry a temperature-compensated crystal oscillator, TCXO, which is accurate to one part per one hundred thousand parts. The Paroscientific transducer output consists of a square wave signal whose frequency varies around the nominal 40 KHz rate. This variance is different for each unit and consequently each unit must be calibrated individually by Paroscientific, Inc. Frequency variations of the instrument are then made with respect to the frequency of the TCXO.

A measurement accuracy of 0.1 mb is expected from currently deployed AWS-2B stations. The sensitivity of the pressure instrument to temperature change is of the order of 1 mb per 20 deg C.

Pressure readings are sent back as 12-bit data, with the actual calibration involving interpolation in two

dimensions left to the post processing of the ARGOS data. Five values of the pressure readings at ten-minute intervals (i.e. 0, -10, -20, -30, -40 min) are sent back with all time base corrections done on-board at the AWS-2B.

3. Wind Direction

The wind direction continues to be simply a voltage reading taken at the arm of a linear potentiometer. This reading is transmitted as an 8-bit quantity. Five wind direction vectors are taken over 40 minutes in 10 minute intervals (i.e. 0, -10, -20, -30, -40 min). The x and y components are saved, averaged and then sent back as two 4-bit numbers. The arctangent of the ratio of these average components produces an average wind direction.

4. Wind Speed

The wind speed is still a voltage reading off the DC generator on the Bendix and is transmitted as an 8-bit number linearly calibrated over the range 0 to 155.5 mi/h, with a 0.6 mi/h resolution. The reading saturates for readings greater than 155.5 mi/h. The transmitted wind speed represents an average of five samples taken at 10 min intervals (i.e. 0, -10, -20, -30, -40 min) as well as the instantaneous wind speed at time "0" min.

III. DATA COLLECTION, LOCATION, AND EVALUATION

A. DATA TRANSMISSION

Data from the AWS are gathered via the Argos Data Collection system aboard the TIROS-N, NOAA 6,7 satellites. The satellite data are initially received at the NASA's Goddard Space Flight Center in Greenbelt, Maryland. Data are then transmitted to France where the initial processing is done. From France the data are sent to the University of Wisconsin at Madison, where processing is completed, and the data archived and made available to research users, generally within a few months after observation time.

B. DATA PROCESSING AND EVALUATION

The AWS-2B data from February 1980 through December 1981 were further computer processed at NPS. These data were received on a more reliable and consistent basis than those gathered during previous time frames due, among other things, to the dedicated AWS-station managers at the University of Wisconsin. As such, the data are useful in their contribution toward establishing a regional climatology of surface wind, temperature and pressure. The main objective of this study has been to evaluate these data so as to evolve a general meteorological "fingerprint" of individual remote AWS sites.

The locations of McMurdo and the AWS sites are shown in Figure 1 with exact coordinates listed in Table I. Data for each station were processed with quality control measures applied to eliminate erroneous reports and duplications, which in some instances accounted for as much as 6% of the data furnished NPS. The number of days actually observed at the AWS sites (Table II) increased markedly since the periods evaluated by the previous researchers (Renard and Salinas, 1977; Scarbro, 1982). The actual number of observations per month greatly increased as well (Tables III, IV, and V), pointing toward the improving reliability of these remote-site observations.

McMurdo station synoptic observations are generally available on tape from the National Climatic Data Center at three-hour intervals from at least the Austral spring through late summer season and with lesser frequency at other times (Table VI). As can be seen from this table there are records for 3695 out of a possible 5600 observations at McMurdo (66%), assuming three-hourly observations as the base. This severely hampered the correlation studies between data at McMurdo and those at the individual AWS, and points to the need for an AWS at McMurdo itself to facilitate future studies of this kind. A McMurdo AWS has since been installed temporarily from December 1981 to December 1982, in connection with wind energy studies.

IV. RESULTS

Summaries of wind, temperature and pressure observations for McMurdo and the surrounding AWS2B stations during the February 1980 - December 1981 time frame will be examined. Particular emphasis will be placed on July and December of 1980 and 1981. These months were selected to show the austral winter and summer seasons, respectively. These data will be compared with climatology summarized by Simpson's (1919) analysis of observations during the British Antarctic Expedition of 1910-1913 and Sinclair's (1982) "Weather Observations in the Ross Island Area, Antarctica".

A. WIND

1. Wind Roses

a. McMurdo Station

Simpson's depiction of wind flow during blizzards across the McMurdo area is shown in Fig. 2. The prevailing winds under these conditions are mostly south/southeasterly. Sinclair's (1982) streamlines of strongest wind flow around Ross Island are shown in Fig. 3. His wind rose for McMurdo (1956-1972 data), shown in Fig. 4, has prevailing winds blowing from a broad easterly sector. Figs. 5-11 depict AWS2B monthly wind speed and direction

summaries derived from summer observations in December 1980 and 1981, and winter observations from July 1980 and 1981. The AWS data for the McMurdo area are supported by the Simpson and Sinclair figures.

In July 1980 (Fig. 5), 31% of the winds were from the east which also provided the maximum wind speed of 14 m/s for the month. July 1981 (Fig. 8) shows a maximum wind of 14 m/s as well, but has a larger percentage (39%) of winds from the eastern sector. The representative summer month of December 1980 (Fig. 6) indicates a maximum wind of 10 m/s with the majority of its winds from the northeast and eastern sectors. December 1981 (Fig. 10), on the other hand, has the majority of wind observations from the southeastern and eastern sectors. Once again there are no winds greater than 10 m/s for this month.

b. Manning (8905)

Manning station was established in a position south of Minna Bluff, which was a previous site for an AWS. During its short tenure Manning has shown consistent winds predominantly from the west. Figure 7, for December 1980, shows 39% of the winds from the western sector with a maximum speed of 18 m/s. December 1981 (Fig. 11) gives a similar distribution with 28% of the winds from the west at a maximum of 13 m/s. During the representative winter month of July 1981 (Fig. 9) Manning shows a considerably greater number of calm reports than it did during the

summer months (38%), but the relative distribution from the west (26%) and the maximum wind speed (19 m/s from the southwest) were consistent with the summer months. The maximum instantaneous wind speed recorded from November 1980 through December 1981 was in June 1981 at 23 m/s.

These data for Manning are fairly consistent with the Simpson and Sinclair results as these figures generally depict prevailing winds from the south/southwest.

c. Marble Point (8906)

There is a gap in Marble Point's wind data from May-November 1981 due to wind sensor failure. The December 1980 results shown in Fig. 6 give a fairly random distribution with the north, southeast and southern sectors all having 20% or more of the monthly winds. The maximum wind speed of 14 m/s is from the south. December 1981 (Fig. 10) shows a similar distribution but with a higher percentage of winds from the north than the previous December. The maximum instantaneous wind speed was less in December 1981 (11 m/s).

July 1980 (Fig. 5) shows a definite shift in the wind pattern to the south (38%) and southwest (14%) with a maximum speed of 26 m/s from the southeast. The maximum speeds recorded over the operating period were 26 m/s in July and October 1980.

AWS data for Marble Point are supported by Simpson and Sinclair's streamlines which show prevailing winds from the south/southeast.

d. Ferrell (8907)

Figure 7 indicates 38% of Ferrell's winds from the southwest in December 1980 with a maximum speed of 14 m/s. December 1981 shows a similar configuration with 29% from the southwest and a maximum speed of 17 m/s (Fig. 11). In July 1981, a greater percentage (45%) of the winds was from the southwest and the maximum speed attained was 22 m/s (Fig. 9). The maximum wind speed recorded at Ferrell was 29 m/s in April 1981. This overall south/southwesterly flow is strongly supported by the streamlines of Simpson and Sinclair.

e. Asgard (8908)

Asgard's wind sensor was inoperative from July 1981 through November 1981. Its winds are affected by local terrain as well as katabatic winds due to the station's location on a ridge in a dry valley. Winds from the interior travel from the southwest through the dry valley and this is reflected in the Asgard winds which are from the south and southwest the year round.

In December 1980 (Fig. 6), 27% and 23% are from the southwest and south, respectively, with a maximum value of 16 m/s from the southwest. December 1981 (Fig. 10) has a larger percentage (40%) from the south, with only 8% from

the southwest. The maximum speed is 13 m/s from the south. Figure 5 for July 1980 gives a distribution of 36% southerly winds and 27% southwesterly. A maximum speed of 25 m/s from the south was recorded. The highest recorded speed for the evaluation period was 31 m/s in October 1980.

f. Meeley (8915)

Meeley station shows pronounced agreement with the streamlines of Simpson and Sinclair. December 1980 and 1981, and July 1981 show 53%, 36%, and 47% of the winds from the southwest, respectively (Figs. 7, 11, and 9). Maximum wind speeds were 15 m/s, 14 m/s, and 25 m/s, respectively. A maximum speed of 30 m/s was recorded in April 1981.

2. Monthly Wind Analyses

a. Wind Speeds

Figures 12 through 30 show plots of wind speed (m/s) versus time (days) for McMurdo and the AWS-2B stations. These plots are for December and July of 1980 and 1981. In spite of the data gaps at McMurdo due to lack of reports, a fair degree of consistency can be noted among the AWS stations and McMurdo in terms of wind velocity. Ferrell and Meeley, which are positioned near one another on the Ross Ice Shelf and experience the same general flow, reflect this similarity in Figs. 18 and 20, Figs. 23 and 24, and Figs. 28 and 30.

It should be noted that in some instances the mean-value and instantaneous-wind profiles appear to be inconsistent. The reader, in referring back to Section II B4, will note that the mean wind is a function of five observations (at ten-minute intervals), not all of which are transmitted as instantaneous.

b. Resultant Winds

Table VII lists the resultant wind data for McMurdo and the five AWS-2B stations. The monthly resultant wind was obtained in the standard way by separating each wind report into its meridional and zonal components, and summing and averaging for the month before reconverting back into a single vector (American Meteorological Society, 1959).

McMurdo's monthly resultant wind is generally from the east. The overall resultant wind for 1980 at McMurdo is 3.5(078) m/s(deg), and for 1981 it is 3.3(083) m/s(deg). The direction range is 53 degrees and the resultant wind speed varies from 2.1 to 5.5 m/s over the months. By comparison, Sinclair's (1982) analysis of McMurdo wind data from March 1956 to December 1972 indicates prevailing easterly (directional range 10 to 40 deg) at a mean wind speed (not resultant) of 5.4 m/s.

Manning (8905) has a predominance of winds from west. Its overall resultant wind for 1981 is 2.3(267)

m/s(deg). Mean speeds ranged from .5 to 4 m/s with a directional range of 76 degrees. Flow interpreted from analyses of Simpson (1919) and Sinclair (1982) would support the westerly direction. Marble Point (8906) has the largest directional range (97 degrees), but still shows a fairly steady southerly direction in its winds for all months except December 1981 when an easterly direction of 106 degrees is noted. An overall mean speed of .6 to 3.7 m/s is obtained. Marble Point's resultant wind for 1980 is 2.3(184) m/s(deg). Ferrell (8907) shows the smallest variability in resultant wind direction with the major portion from the southwest as expected from Sinclair and Simpson's figures. Ferrell's resultant wind for 1981 is 4.6(208) m/s(deg). A variance of only 12 degrees is noted for the entire reporting period. Mean vector wind speeds varied from 2.9 to 8.3 m/s on a monthly basis. Meeley (8915), which is close to Ferrell, shows a similar wind condition with an overall resultant wind of 4.9(212) m/s(deg) for 1981 and mean speeds varying from 3.0 to 8.1 m/s. Asgard (8908) generally displays south-southwesterly flow with a range of 47 degrees noted from February 1980 to December 1981. The mean wind speed varies on a monthly basis from 1.1 to 5.4 m/s. Its overall resultant wind for 1980 is 2.9(203) m/s(deg).

Overall, the annual variation consists of a seasonal periodicity, with a minimum in the summer and maximum in the winter and a pronounced secondary maximum in February and March, according to Simpson (1919). The resultant winds from AWS-2B stations agree with this conclusion. Increased wind velocity in the winter is, in part, due to the greater temperature difference between the continent and the ocean during that season.

c. Diurnal Wind Variations

Figures 31 through 45 show diurnal variations in wind speed on an hourly basis for December and July 1980 and 1981. Figure 46 is from Simpson; it shows that, except in the winter months, the maximum wind velocity is in the early afternoon with the minimum reached after midnight. This is explained by Simpson to be due to convection currents which are set up during the day where upper-level air moves with higher speed than that at the lower levels, with convective currents conveying momentum from the upper air to the lower air. At night in the absence of these convective currents the upper-level air movement does not affect that of the lower-level air. Simpson found that the variations were random from year to year during the winter months, and doubted the significance of variations shown during the winter.

Figure 31 depicting wind speed for July 1980 at Marble Point, shows several seemingly random increases in wind over a 24 h period which do not correspond to the similarly random maximums in Fig. 32 for Asgard. During the summer, however, there appears to be a consistent peak around 0002Z +/- 1 h or 1400 +/- 1 h local among the stations. The variations in the maximum wind between the summer calm and winter stormy seasons are evident in these diagrams, but the graphical scale makes subtle changes difficult to compare with those of Simpson (1919).

B. TEMPERATURE

1. Monthly Means and Extremes

a. McMurdo

The monthly means and extremes of McMurdo temperature climatology (U.S. Naval Weather Service, 1970) are depicted in Fig. 47. Data for 1980 and 1981 for the AWS-2B stations are represented in Figs. 48-57. Climatologically, the temperatures drop sharply during the transition months February-March and rise sharply during the transition months October-November. The summer months of December and January are expected to maintain relatively mild temperatures and the winter months June-September should have approximately the same mean, namely very cold monthly temperatures. This phenomenon is called the coreless or "kernlose" winter of the Antarctic. The sharp

increase in temperature prior to the summer is due in part to the influx of warmer maritime air from the coastal areas. The sharp decrease in temperature during the winter is due to the reduction of insolation at the close of the summer, which begins in the interior and progresses seaward, strengthening the temperature gradient which in turn increases cyclonic activity and low-level meridional flow toward the ocean. This meridional return flow aloft with mixing helps to counter the rapid radiational cooling resulting in the coreless winter. McMurdo climatology reflects this phenomenon as do the 1980 and 1981 AWS-2B data.

b. Marble Point (8906)

Figure 49 shows the 1980 data for Marble Point; it supports the concept of the coreless winter. The absolute maximum for 1980 varies from 4.7 C in December to -11.2 C in September for a range of 15.9 C, while the absolute minimum temperature varies from -11.9 C in December to -38.7 C in August for a range of 26.8 C. The average daily maximum temperature varies from a high of -0.3 C in December to -22.0 C in September for a difference of 21.7 C. The average daily minimum temperature went from -8.9 C in February to -29.0 C in June for a net change of 20.1 C.

The monthly mean exhibits a large drop of 8.7 C between February and March and then remains around -20.0 C for the winter except for the anomalous months of June and

September which were several degrees cooler than the other winter months. The major increase in temperature occurs between October and November when the mean rose 10.1 C.

Overall, Marble Point is warmer than the McMurdo climatology except for the anomalous months of June and September. In Fig. 54 the 1981 data are represented for Marble Point. There is a major drop in temperature between March and April vice February and March. The 1981 winter has much more variability around the mean than the 1980 winter and does not represent the coreless winter concept as well as 1980. Marble Point's overall temperatures are higher for both years than those of McMurdo and the other AWS-2B stations. As the patterns of the other stations are similar to that of Marble Point, only a cursory review will be made of them.

c. Manning (8905)

Only two months of data were available for Manning during 1980 and these are shown in Fig. 48. In 1981 Manning showed steady drops in the mean temperature from January to March, with a final sharp drop between March and April (Fig. 53). The mean fluctuated in the same pattern as that of Marble Point during the same period, with Marble Point recording temperatures approximately eight degrees warmer. Manning also shows greater extremes in temperature than does Marble Point.

d. Ferrell (8907)

At Ferrell only one month of data was recorded in 1980 (Fig. 50), but the 1981 data (in Fig. 55) show the same type of pattern as at Marble Point and Manning stations. Ferrell is several degrees colder than Manning but shows approximately the same variations in extremes.

e. Asgard (8908)

Asgard shows (Fig. 51) a good approximation of the coreless winter with a large decrease in the mean temperature between February and March and a fairly constant mean of -26 C through October. A sharp rise in temperature is observed between October and November. Figure 56, for 1981, indicates a major drop in temperature between March and April as did Marble Point in that same year. Overall, the 1981 winter is colder than the 1980 winter.

f. Meeley (8915)

Figure 52 shows the 1980 data for December and Fig. 57 the 1982 data for the entire year. Overall, Meeley has the same pattern and characteristics as Ferrell which has already been discussed.

2. <u>Monthly Temperature Profiles</u>

Monthly profiles of temperature are shown in Figs. 58-77 for McMurdo and each AWS-2B station. These plots help show relations of the monthly means to individual days during each month and are plotted for the representative

months of summer (December 1980 and 1981) and winter (July 1980 and 1981).

Figures 59b, 63b, 68b, and 74b for Marble Point, taken as representative of the McMurdo area, show the large variability during the stormy winter season as compared to the more quiescent summer season. The transition months of April and October reflect the variability associated with seasonal change.

When comparing the locations to one another a definite correlation can be seen among the five stations surrounding McMurdo, with Asgard and its dry valley locale the most dissimilar among these five. Using July 1981 as an example, a comparison of the stations shows similar patterns with slight leads and lags. The similarity of the general temperature pattern of McMurdo to that of its surrounding AWS-2B platforms indicates how the same synoptic systems affect this entire area. The scale of these figures is too small to graphically illustrate actual lag times thus this problem is addressed quantitatively in the regression section of the study. A measure of the variation in detail at McMurdo and the AWS-2B stations is given by the standard deviations in Table VIII.

3. Diurnal Temperature Variations

Figures 78 through 94 show the diurnal temperature variations at each AWS-2B site for representative summer

months December 1980 and 1981, and the representative winter months July 1980 and 1981. For all sites consider local time equal to Greenwich time + 12 hours. Local time loses physical significance during the dark winter months. The average hourly variation in the maximum, minimum and mean temperature for the month of December at Marble Point can be seen in Figs. 81 and 91. The diurnal plots for the remaining AWS-2B sites, in summer, show the same overall variation as at Marble Point. Although the actual diurnal range is small during the summer, the diurnal plots do illustrate a slight daily variation related to the traverse of the sun (i.e., early afternoon maximum; early morning minimum).

The average diurnal variations in winter are insignificant and irregular. Again Marble Point is a good example; however, there are large variations in temperature hour to hour. Largely, these are fluctuations due to variations in wind direction and speed, both as a function of local and regional effects as well as synoptic-scale forcing. These patterns, occurring randomly, offset each other during the course of the month and when averaged together give the appearance of negligible diurnal variation. In reality, most of the largest diurnal variations occur during the winter; plots of mean monthly diurnal values such as Fig. 86, mask these variations.

Hisdal (1960) in his meteorological studies at the South Pole discovered that days with clear skies and/or light to moderate winds showed minimum temperature near 1200 GMT. When cloudy, windy days occurred the maximum temperature was near 1200 GMT. Hisdal explained this phenomenon in terms of an "automatic" daily variation resulting from varying synoptic conditions of particular days (Fig. 95). He suggests that the automatic daily variation imposes a statistical bias on any real diurnal variation that might be present. He also believes that this bias could totally mask diurnal variations, presumably for Antarctic locations at other than South Pole.

Barrigar (1963) noted in his statistical study of diurnal temperature variations that no diurnal temperature exists during the polar night and that synoptic fluctuations are the cause of the maxima that appear in the daily temperature trend.

C. SURFACE PRESSURE PROFILES

1. Introduction

The average surface pressure at each AWS reflects station elevation; collectively, the profile features are very similar due to the close adjacency of the stations and the predominance of a scale of weather systems exceeding the distance between the stations.

2. Monthly Surface Pressure Profiles

Figures 58-77 show the monthly surface pressure profiles for McMurdo (actually sea-level) and the AWS-2B stations for December 1980 and 1981, and July 1980 and 1981. For each of these figures the time scale is identical, while on the pressure scale the range is constant, variations in magnitude being necessary due to differences in station elevation.

McMurdo's sea-level pressure in December 1980 (Fig. 61a) is fairly steady, averaging 985 mb over the period from 10 to 31 December. The large drop in pressure observed between the 4th and 7th relates well to that of other AWS-2B stations.

Although as a first approximation McMurdo and AWS profiles are identical, there is evidence of a lead-lag relationahip among these stations, which will be discussed quantitatively in the section on regression. A measure of the variation in detail at McMurdo (observation interval 3-h) and AWS stations (observation interval about every 10 min at 2-h intervals) is given by the standard deviations in Table IX. These deviations appear to maximize in the transition seasons as with temperature, but not necessarily in the same months.

During the winter there are increased pressure fluctuations due to the harsh winter storm systems. Once again

the pattern is similar between McMurdo and its surrounding stations. The range of pressure fluctuation for July 1981 is approximately 42 mb for each of the stations as opposed to the average fluctuation range of 20 mb for December 1980.

3. Diurnal Pressure Variations

Diurnal pressure variations for McMurdo and the surrounding AWS-2B stations are portrayed in Figs. 96-112. Generally speaking, miniscule mean diurnal variations in pressure are expected as surface variations of this type tend to decrease poleward especially in view of the snow/ice covered surface. The variation for December 1980 at Marble Point is shown as an example (Fig. 99). There is very little variation about the mean, with an absolute range of around 20 mb. Figure 104 for July 1981 exemplifies the winter variation for Marble Point. Again, there is little variation in the diurnal mean, but the diurnal range increases to 42 mb as expected for winter. Pressure changes due to passing synoptic and sub-synoptic scale variation, occurring without diurnal bias, tend to average out over a month's period, giving insignificant variations over the 24-h period on this scale of figure.

Simpson's plot of daily variation of pressure curves over four years at McMurdo (Fig. 113) shows evidence of two maxima and two minima for each month of the year. His figures, however, show maximum diurnal variations on the order of 0.5 mb which cannot be seen on the scale of AWS-2B diurnal profiles shown here.

D. REGRESSION RESULTS

A regression study was done for the combined months of December 1980 and 1981 to determine whether the data of AWS stations could be utilized for forecasting purposes at McMurdo. The results in Tables X-XIII indicate the potential in this area.

For three- and six-hourly temperature forecasts at McMurdo (predictands), McMurdo data itself plays a more important role than the AWS stations but the AWS data do make significant contributions. Considering all time intervals, the 3-h forecasts are more credible than the 6-h forecasts but there are exceptions, e.g. in the case of stratifying the data by 00-06 GMT, and by 06-12 GMT and 18-00 GMT using Marble Point data only as predictors. The predictand variance explained by the predictors (R^2) is generally higher for the equations developed by data stratified into six-hour intervals.

Three- and six-hour wind forecasts for McMurdo were developed with much less data than for the temperature equations, due to the nature of the differences in the AWS wind and temperature observations. McMurdo data at three hours before observation time are the only significant predictors, totally excluding observations from the AWS data.

V. FINAL REMARKS

The evolution of the Automatic Weather Station observations to their present level of quality and quantity has resulted in data useful to both research and operations. The climatological analyses and regression experiments reported on here give examples of simple applications of the AWS data to increase the meteorological knowledge of one important region of the Antarctic, namely the Ross Sea/ Ice Shelf area near McMurdo.

TABLE I

McMurdo and AWS-2B Station Locations

Station: ID, Name	Latitude	Longitude	Elevation	Distance From McMurdo	Initial Operating Date
8905 Manning	78^{o} 46' S	166^{o} 51' E	30 m	178^{o}/100.8 km	26 Nov 80
8906 Marble Pt	77^{o} 26' S	163^{o} 45' E	120 m	302^{o}/ 83 km	19 Jan 79
8907 Ferrell	78^{o} 01' S	170^{o} 48' E	30 m	104^{o}/ 97.9 km	11 Dec 80
8908 Asgard	77^{o} 36' S	161^{o} 04' E	1750 m	279^{o}/135.1 km	24 Jan 79
8915 Meeley	78^{o} 31'	170^{o} 11' E	30 m	134^{o}/108.3 km	04 Dec 80
89664 McMurdo	77^{o} 51' S	166^{o} 40' E	24 m	--	--

TABLE II

Days with AWS Observations

1980	8905	8906	8907	8908	8915
FEB		25		25	
MAR		31		31	
APR		30		30	
MAY		31		31	
JUN		30		30	
JUL		31		31	
AUG		31		31	
SEP		30		30	
OCT		31		31	
NOV	6	30		30	
DEC	31	31	22	31	28
1981					
JAN	25	25	25	25	25
FEB	28	28	28	28	28
MAR	31	31	31	31	31
APR	30	30	30	30	30
MAY	31	31	31	31	31
JUN	30	30	30	30	30
JUL	31	31	31	31	31
AUG	31	31	31	31	31
SEP	30	30	30	30	30
OCT	31	31	31	31	31
NOV	30	30	30	30	30
DEC	31	31	31	31	31

TABLE III

Number of AWS Surface Temperature Observations

1980	8905	8906	8907	8908	8915
FEB		2603		2532	
MAR		3447		3314	
APR		3337		3276	
MAY		3495		3394	
JUN		3118		3063	
JUL		3282		3229	
AUG		3379		3326	
SEP		3232		3189	
OCT		3386		3320	
NOV		3270		3174	
DEC	3400	3368	2337	3248	3064
1981					
*JAN	1937	1915	1921	1869	1957
**FEB	3097	3125	3139	3024	3174
MAR	2529	2539	2549	2401	2565
APR	2471	2431	2184	2296	2527
MAY	2659	2601	2525	2479	2619
***JUN	2661	2650	2643	2458	2730
JUL	3563	3564	3528	2985	3639
AUG	3534	3574	3554	2929	3721
SEP	3463	3453	3247	2841	3501
OCT	3742	3664	3651	2978	3747
NOV	3462	3446	3466	2856	3506
DEC	3648	3609	3596	3516	3657

*Data missing 9-15 Jan 81

**Loss of TIROS-N 27 Feb 81

***Launch of NOAA7 22 Jun 81

TABLE IV

Number of AWS Surface Pressure Observations

1980	8905	8906	8907	8908	8915
FEB		2603		2549	
MAR		3447		3326	
APR		3351		3276	
MAY		3522		3406	
JUN		3161		3077	
JUL		3322		3257	
AUG		3430		3342	
SEP		3266		3209	
OCT		3410		3324	
NOV		3270		3178	
DEC	3414	3368	2346	3278	3067
1981					
*JAN	1941	1920	1921	1877	1965
**FEB	3153	3125	3149	3036	3179
MAR	2557	2543	2557	2409	2569
APR	2515	2439	2188	2324	2531
MAY	2659	2605	2545	2503	2627
***JUN	2709	2650	2655	2482	2734
JUL	3651	3600	3562	2986	3656
AUG	3709	3630	3586	2932	3737
SEP	3497	3464	3264	2845	3504
OCT	3728	3696	3657	2983	3761
NOV	3482	3451	3466	2856	3511
DEC	3656	3613	3596	3516	3665

*Data missing 9-15 Jan 81

**Loss of TIROS-N 27 Feb 81

***Launch of NOAA7 22 Jun 81

TABLE V

Number of AWS Surface Wind Observations

1980	8905	8906	8907	8908	8915
FEB		1039		951	
MAR		1420		1280	
APR		1370		1248	
MAY		1437		1294	
JUN		1273		1146	
JUL		1347		1245	
AUG		1416		1286	
SEP		1302		1219	
OCT		1381		1265	
NOV	253	1330		1198	
DEC	1423	1345	954	1214	1289
1981					
*JAN	862	837	862	764	896
**FEB	1324	1268	1326	1137	1335
MAR	853	839	849	729	865
APR	858	791	668	708	875
MAY	902	437	813	771	871
***JUN	982	0	932	154	1003
JUL	1595	0	1472	0	1613
AUG	1587	0	1412	0	1612
SEP	1527	0	1277	0	1537
OCT	1614	0	1529	0	1642
NOV	1522	74	1507	74	1546
DEC	1594	1551	1577	1404	1625

*Data missing 9-15 Jan 81

**Loss of TIROS-N 27 Feb 81

***Launch of NOAA7 22 Jun 81

TABLE VI

Density of McMurdo Observations

1980	Number of Observations	Days with Observations
FEB	181	29
MAR	110	31
APR	86	30
MAY	122	31
JUN	85	30
JUL	102	31
AUG	132	31
SEP	140	30
OCT	219	31
NOV	222	30
DEC	226	31
1981		
JAN	232	31
FEB	148	28
MAR	67	31
APR	176	30
MAY	189	31
JUN	184	30
JUL	195	31
AUG	177	31
SEP	187	30
OCT	170	31
NOV	130	30
DEC	215	31
	3695 Observations	700 Days

TABLE VII

Resultant Wind Data

Wind Speed / Wind Direction
(m/s) (Deg)

	McMurdo (89664)	Manning 8905	Marb.Pt 8906	Ferrell 8907	Asgard 8908	Meeley 8915
FEB80	4.1/064	---/---	2.4/168	---/---	1.4/205	---/---
MAR80	5.5/076	---/---	3.7/174	---/---	1.9/199	---/---
APR80	4.3/084	---/---	2.3/203	---/---	2.6/199	---/---
MAY80	2.9/071	---/---	2.2/190	---/---	3.7/200	---/---
JUN80	3.9/068	---/---	2.3/185	---/---	3.1/201	---/---
JUL80	3.2/078	---/---	2.2/202	---/---	3.8/201	---/---
AUG80	4.6/088	---/---	2.6/185	---/---	2.6/200	---/---
SEP80	2.7/086	---/---	1.4/196	---/---	3.9/206	---/---
OCT80	3.9/100	---/---	3.4/179	---/---	5.4/204	---/---
NOV80	2.9/075	0.5/333	1.5/171	---/---	1.1/216	---/---
DEC80	2.4/065	3.6/268	1.1/159	3.0/214	2.1/206	4.4/214
Overall	3.5/078		2.3/184		2.9/203	
JAN81	3.3/060	3.8/272	2.7/154	3.9/212	1.9/185	4.8/214
FEB81	2.6/113	4.0/264	3.0/171	4.6/205	2.2/223	5.1/212
MAR81	4.6/073	3.6/265	2.6/189	5.6/207	2.6/220	6.8/210
APR81	4.3/094	2.0/269	2.8/191	4.9/204	4.1/221	3.5/213
MAY81	4.4/095	3.7/257	2.8/188	8.3/204	3.8/228	8.1/207
JUN81	2.5/071	2.1/260	---/---	6.5/213	7.8/229	7.0/212
JUL81	3.8/073	2.2/274	---/---	4.4/218	---/---	4.9/215
AUG81	4.2/074	1.7/280	---/---	4.8/208	---/---	4.5/209
SEP81	4.9/086	0.8/276	---/---	4.8/202	---/---	5.0/208
OCT81	2.1/073	0.8/287	---/---	3.4/210	---/---	3.8/219
NOV81	2.5/098	2.7/266	1.3/177	4.2/211	4.0/182	4.5/216
DEC81	2.3/099	2.5/259	0.6/106	2.9/209	1.9/185	3.0/211
Overall	3.3/083	2.3/267		4.6/208		4.9/212

TABLE VIII

Average Temperature and Standard Deviation

	Marble Pt 8906		Asgard 8908		Manning 8905		Ferrell 8907		Meeley 8915	
1980	AveTemp	S.D.	AveTemp	S.D.	AveTemp	S.D.	AveTemp	S.D.	AveTemp	S.D.
FEB	- 7.3	3.1	-16.9	3.0						
MAR	-16.0	3.6	-23.7	4.0						
APR	-18.5	4.0	-25.5	3.5						
MAY	-20.1	5.4	-25.4	4.9						
JUN	-25.2	4.1	-28.5	4.7						
JUL	-23.1	5.6	-26.3	4.8						
AUG	-22.8	5.5	-26.4	4.8						
SEP	-25.6	4.6	-26.2	5.2						
OCT	-19.0	8.8	-25.0	6.7						
NOV	- 8.9	2.9	-16.9	3.3	-12.1	3.1				
DEC	- 2.8	3.2	-12.1	2.3	- 6.3	4.1	- 7.2	2.5	- 6.7	2.7
1981										
JAN	- 2.8	2.4	-12.9	3.1	- 8.5	3.9	-10.2	3.7	- 9.5	3.5
FEB	- 8.3	4.2	-18.0	4.3	-14.7	7.2	-15.1	6.5	-14.9	6.4
MAR	-12.3	3.9	-20.2	4.6	-18.9	5.9	-20.5	5.3	-20.3	5.3
APR	-23.4	9.5	-27.5	7.8	-33.2	11.3	-32.1	11.0	-35.3	11.2
MAY	-21.3	6.1	-26.8	4.0	-30.6	8.7	-31.0	7.5	-31.2	7.5
JUN	-18.9	5.5	-26.1	5.3	-27.2	6.9	-29.4	5.9	-28.7	5.9
JUL	-21.6	4.8	-27.4	4.6	-30.5	7.2	-33.3	6.1	-33.1	6.3
AUG	-24.2	6.0	-27.1	5.4	-32.4	8.3	-35.5	6.7	-36.1	7.0
SEP	-27.9	5.1	-27.2	5.1	-36.3	7.3	-36.7	7.5	-37.6	7.8
OCT	-20.6	5.9	-24.4	5.6	-27.2	8.7	-27.5	8.6	-27.6	8.4
NOV	-11.6	5.0	-19.3	4.7	-15.9	5.3	-17.8	5.1	-17.7	5.2
DEC	- 4.0	2.0	-12.6	1.7	- 6.9	2.7	- 8.0	2.6	- 7.9	2.7

TABLE IX

Average Pressure and Standard Deviation

	Marble Pt 8906		Asgard 8908		Manning 8905		Ferrell 8907		Meeley 8915	
1980	AvePress	S.D.	AvePress	S.D.	AvePress	S.D.	AvePress	S.D.	AvePress	S.D.
FEB	979.4	5.9	808.1	4.6						
MAR	977.6	7.7	802.3	5.9						
APR	980.0	10.8	803.7	7.4						
MAY	974.9	11.3	799.8	10.0						
JUN	971.4	10.0	794.1	8.5						
JUL	980.9	10.1	803.8	8.7						
AUG	975.8	5.6	799.7	5.6						
SEP	979.9	11.8	802.3	10.6						
OCT	962.8	8.4	789.8	9.2						
NOV	982.0	5.6	810.3	3.8	986.8	2.7				
DEC	975.9	5.1	808.4	3.7	982.0	5.5	986.3	3.6	983.2	5.8
1981										
JAN	972.8	6.0	805.8	5.1	979.2	6.1	982.0	5.6	981.4	5.6
FEB	977.8	5.4	807.3	3.5	985.0	5.8	987.2	6.2	986.6	6.1
MAR	979.8	8.3	807.7	7.7	987.6	8.7	989.7	8.5	988.8	8.7
APR	981.5	11.2	803.1	12.8	989.7	11.6	993.7	11.3	991.5	11.1
MAY	974.5	9.6	799.2	6.4	984.1	9.9	984.2	10.4	984.1	10.6
JUN	968.8	11.8	795.3	10.8	977.0	12.2	978.9	12.6	977.9	12.4
JUL	976.7	8.5	801.9	7.7	984.7	8.5	987.1	8.7	985.8	8.8
AUG	984.4	12.3	807.1	10.9	993.0	13.2	994.8	13.4	994.0	13.4
SEP	977.9	8.7	800.5	7.3	986.5	9.0	988.7	9.4	987.9	9.2
OCT	970.2	7.9	796.5	6.6	978.0	8.1	980.6	8.3	979.8	8.3
NOV	967.2	5.2	797.2	5.8	974.2	5.5	977.2	5.4	975.9	5.7
DEC	968.9	5.3	802.5	4.8	975.0	5.6	978.4	5.3	977.6	5.6

TABLE X. Multiple linear regression equations for forecasting surface temperature at McMurdo (= predictand) for observation time + 3 h and observation time + 6 h, considering all observations, December 1980 and 1981. In one sample, only AWS 8905, 8907 and 8915 data are considered as predictors; in another sample only AWS 8906 data are considered as predictors.
Predictor legend: M or M#=McMurdo data at observation time or at 0-3 or 0-6 h; A( ) or A#( ) = AWS data at observation time or at 0-3 or 0-6 h for AWS site 89xx.

Temp at 0+3h (194 obsns)	Equation (8905,8907,8915)	R^2 (%)
	10.026	
	0.416 M	31.7
	-1.653 A (8905)	4.5
	0.132 M6	1.5
		37.7

Temp at 0+3h (243 obsns)	Equation (8906)	R^2 (%)
	-0.010	
	0.707 A	39.6
	0.234 M	3.2
		42.8

Temp at 0+6h (194 obsns)	Equation (8905,8907,8915)	R^2 (%)
	19.527	
	0.336 M	15.7
	0.203 M6	3.1
		18.8

Temp at 0+6h (242 obsns)	Equation (8906)	R^2 (%)
	-0.165	
	0.687 A	35.9
	0.174 M	1.9
		37.8

TABLE XI. Multiple linear regression equations for forecasting surface temperature at McMurdo, (= predictand) for observation time + 3 h and observation time + 6 h, considering 00-06 GMT and 06-12 GMT observations only, December 1980 and 1981. In one sample, only AWS 8905, 8907 and 8915 data are considered as predictors; in another sample only AWS 8906 data are considered as predictors. Predictor legend: M or M#=McMurdo data at observation time or at 0-3 or 0-6 h; A( ) or A#( ) = AWS data at observation time or at 0-3 or 0-6 h for AWS site 89xx.

(00-06Z forecasts)

Temp at 0+3h	Equation (8905,8907,8915)	R^2 (%)
(75 obsns)	4.874	
	0.471	34.0
	-2.976 A (8915)	8.0
		42.0
Temp at 0+3h	Equation (8906)	R^2 (%)
(93 obsns)	-0.062	
	0.708 M6	23.7
Temp at 0+6h	Equation (8905,8907,8915)	R^2 (%)
(74 obsns)	19.181	
	0.270 M	17.2
	0.255 M6	5.9
	-1.989 A (8905)	5.0
	5.938 A3 (8915)	5.9
	-5.306 A (8915)	9.1
		43.1
Temp at 0+6h	Equation (8906)	R^2 (%)
(93 obsns)	-0.423	
	0.879 A1	25.6

(06-12Z forecasts)

Temp at 0+3h	Equation (8905,8907,8915)	R^2 (%)
(75 obsns)	27.901	
	0.458 M	31.5
Temp at 0+3h	Equation (8906)	R^2 (%)
(93 obsns)	-0.727	
	0.745 A	41.5
	0.193 M	4.8
		46.3
Temp at 0+6h	Equation (8905,8907,8915)	R^2 (%)
(75 obsns)	41.623	
	0.213	11.4
Temp at 0+6h	Equation (8906)	R^2 (%)
(93 obsns)	-1.519	
	0.739 A3	50.9
	0.158 M	4.7
		55.6

TABLE XII. Multiple linear regression equations for forecasting surface temperature at McMurdo, (= predictand) for observation time + 3 h and observation time + 6 h, considering 12-18 GMT and 18-00 GMT observations only, December 1980 and 1981. In one sample, only AWS 8905, 8907 and 8915 data are considered as predictors. In another sample only AWS 8906 data are considered as predictors. Predictor legend: M or M#=McMurdo data at observation time or at 0-3 or 0-6 h; A( ) or A#( ) = AWS data at observation time or at 0-3 or 0-6 h for AWS site 89xx.

(12-18Z forecasts)

		R^2 (%)
Temp at 0+3h (71 obsns)	Equation (8905,8907,8915)	R^2 (%)
	5.064	
	0.648 M	56.6
	0.258 M3	6.9
		63.5
Temp at 0+3h (95 obsns)	Equation (8906)	R^2 (%)
	0.045	
	0.637 A	42.6
	0.293 M	4.6
		47.2
Temp at 0+6h (75 obsns)	Equation (8905,8907,8915)	R^2 (%)
	-1.083	
	0.893 M	39.9
Temp at 0+6h (98 obsns)	Equation (8906)	R^2 (%)
	1.116	
	0.751 A	56.5
	0.284 M	4.8
		61.3

(18-00Z forecasts)

Temp at 0+3h (69 obsns)	Equation (8905,8907,8915)	R^2 (%)
	-1.565	
	0.534 M	33.5
	-3.119 A (8905)	9.1
		42.6
Temp at 0+3h (83 obsns)	Equation (8906)	R^2 (%)
	0.411	
	0.426	73.6
	0.507 A (8906)	6.3
		79.9
Temp at 0+6h (74 obsns)	Equation (8905,8907,8915)	R^2 (%)
	-9.478	
	0.595 M6	21.8
	-2.921 A (8905)	7.7
		29.5
Temp at 0+6h (89 obsns)	Equation (8906)	R^2 (%)
	0.385	
	0.720 M	29.4

TABLE XIII. Multiple linear regression equations for forecasting surface wind speed at McMurdo (= predictand) for observation time + 3 h and observation time + 6 h, considering all observations, December 1980 and 1981. In one sample, only AWS 8905, 8907 and 8915 data are considered as predictors. In another sample only AWS 8906 data are considered as predictors.
Predictor legend: M or M#=McMurdo data at observation time or at 0-3 or 0-6 h; A( ) or A#( ) = AWS data at observation time or at 0-3 or 0-6 h for AWS site 89xx.

Wind speed at 0+3h (39 obsns)	Equation (8905,8915)	R^2 (%)
	1.391	
	0.644 M	33.9
Wind speed at 0+3h (50 obsns)	Equation (8906)	R^2 (%)
	1.102	
	0.458 M3	46.1
	0.377	6.4
		52.5
Wind speed at 0+6h (43 obsns)	Equation (8905,8915)	R^2 (%)
	1.415	
	0.713 M	41.0
Wind speed at 0+6h (50 obsns)	Equation (8906)	R^2 (%)
	1.797	
	0.608 M	33.3

TABLE XIV. Multiple linear regression equations for forecasting surface wind speed at McMurdo, (= predictand) for observation time +3 h and observation time +6 h, considering 00-12 GMT and 12-00 GMT observations only, December 1980 and 1981. In one sample, only AWS 8905, 8907 and 8915 data are considered as predictors. In another sample only AWS 8906 data are considered as predictors. Predictor legend: M or M#=McMurdo data at observation time or at 0-3 and 0-6 h; A( ) or A#( ) = AWS data at observation time or at 0-3 or 0-6 h for AWS site 89xx.

(00-12Z forecasts)

Wind speed	Equation	(8905,8915)	R^2 (%)
at 0+3h		4.000	
(27 obsns)		1.385	38.3
Wind speed	Equation	(8906)	R^2 (%)
at 0+3h		1.421	
(28 obsns)		0.705	45.9
Wind speed	Equation	(8905,8915)	R^2 (%)
at 0+6h		1.401	
(29 obsns)		0.771 M	53.3
Wind speed	Equation	(8906)	R^2 (%)
at 0+6h		1.563	
(31 obsns)		0.678 M	48.8

(12-00Z forecasts)

Wind speed	Equation	(8905,8915)	R^2 (%)
at 0+3h		1.748	
(27 obsns)		0.589	33.4
Wind speed	Equation	(8906)	R^2 (%)
at 0+3h		1.533	
(37 obsns)		0.745	59.4
Wind speed	Equation	(8905,8915)	R^2 (%)
at 0+6h		1.600	
(30 obsns)		0.705	39.1
Wind speed	Equation	(8906)	R^2 (%)
at 0+6h		2.150	
(36 obsns)		0.558 M	27.3

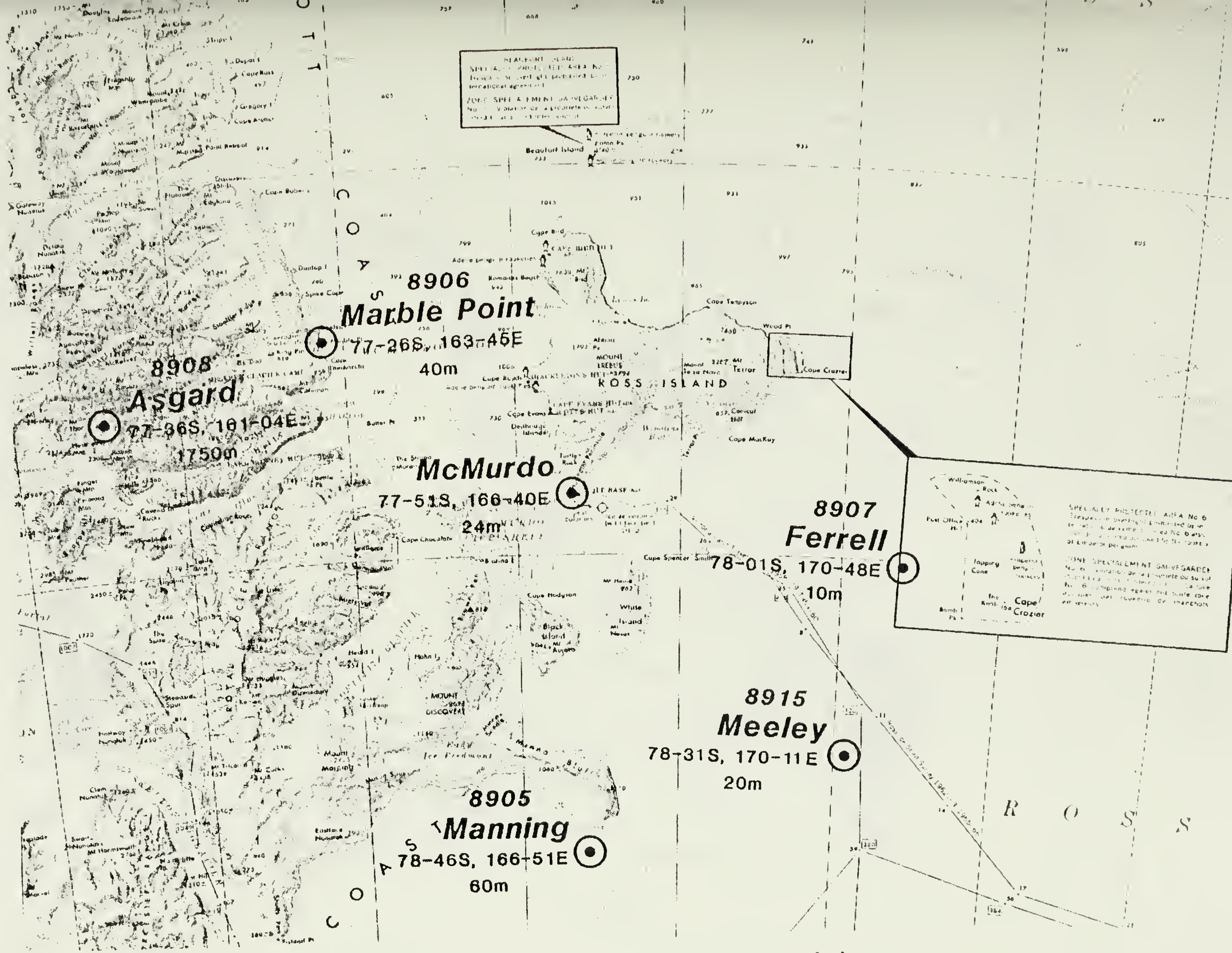


Figure 1. AWS Deployment - Ross Island Area.

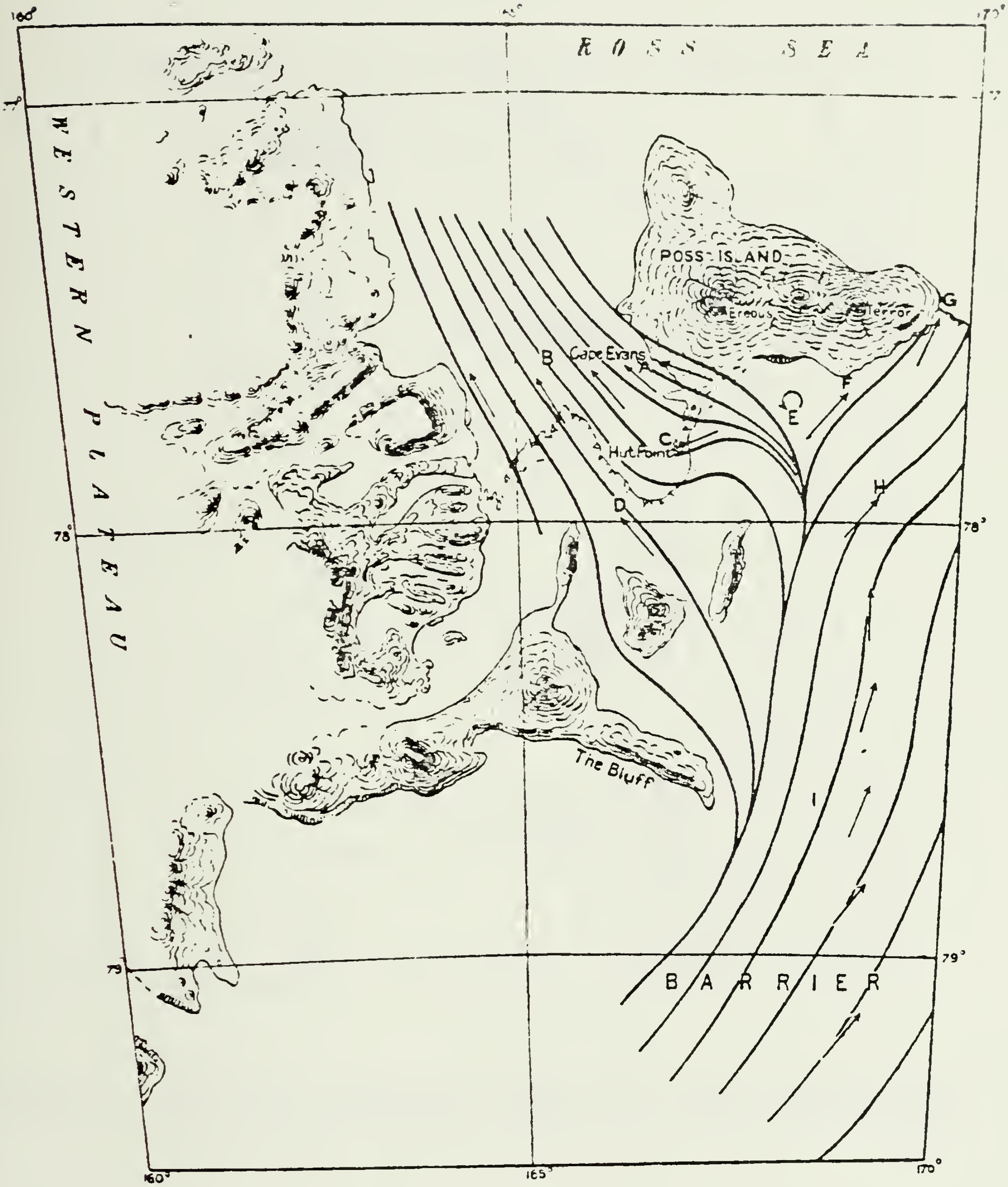


Figure 2. Surface Wind Directions during Blizzards in the Ross Sea/Ice Shelf Area (Simpson, 1919)

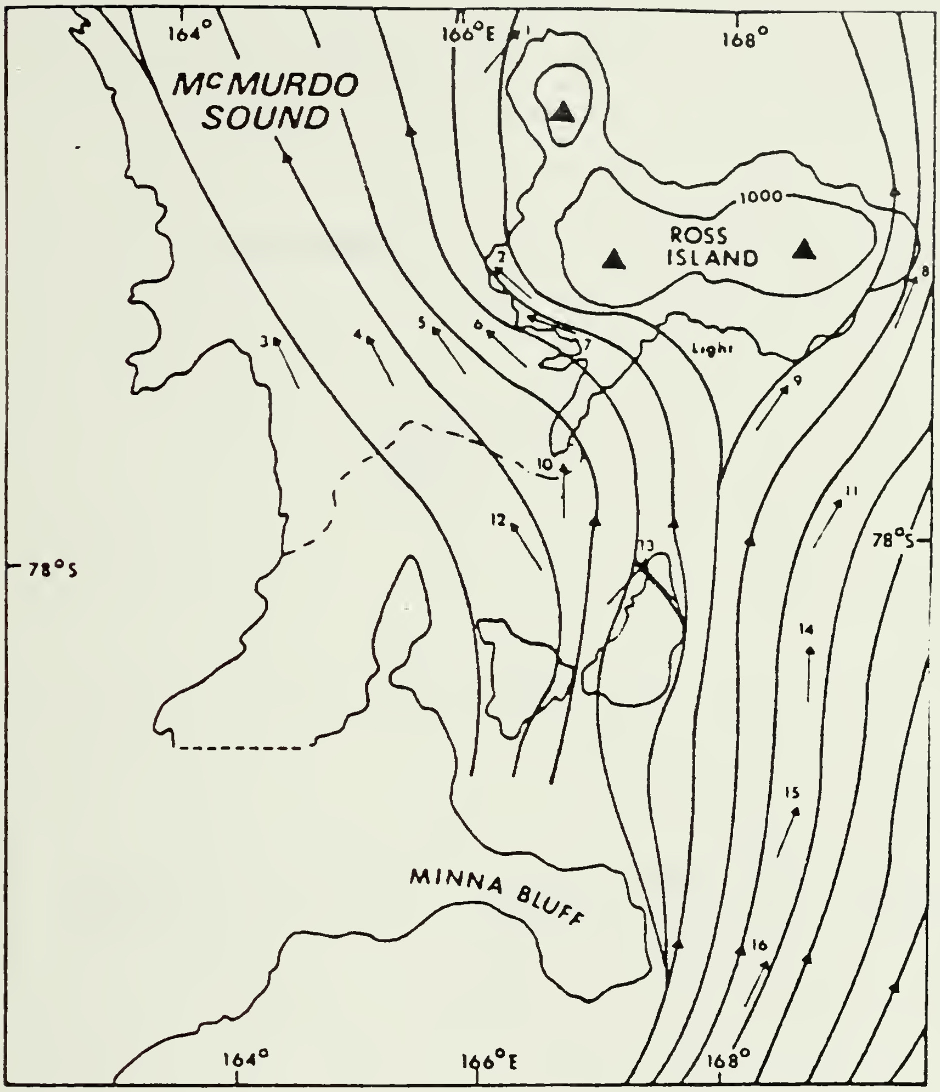


Figure 3. Surface Streamlines Associated with Strong Flow in the Ross Sea/Ice Shelf Area (Sinclair, 1982)

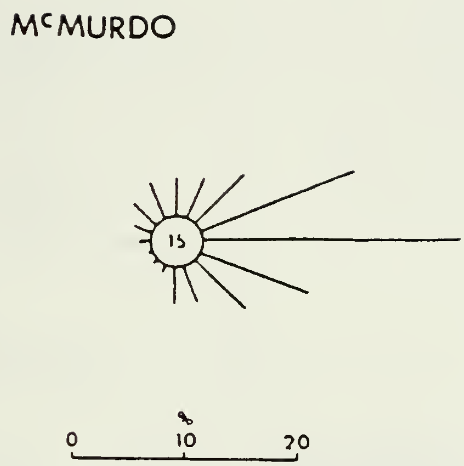


Figure 4. Surface Wind Rose, McMurdo, 1956-1972 (Sinclair, 1982)

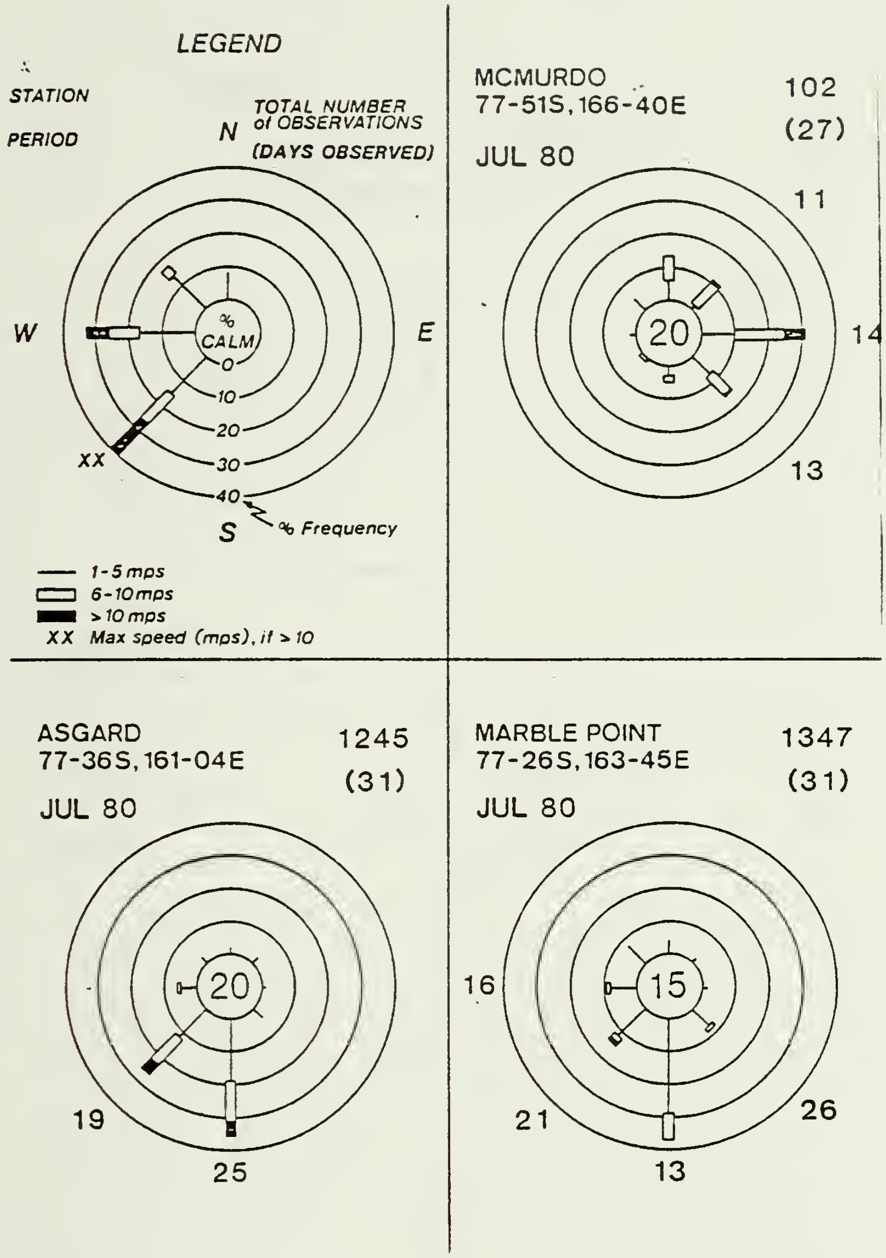


Figure 5. Surface Wind Roses for McMurdo, Asgard and Marble Point, July 1980

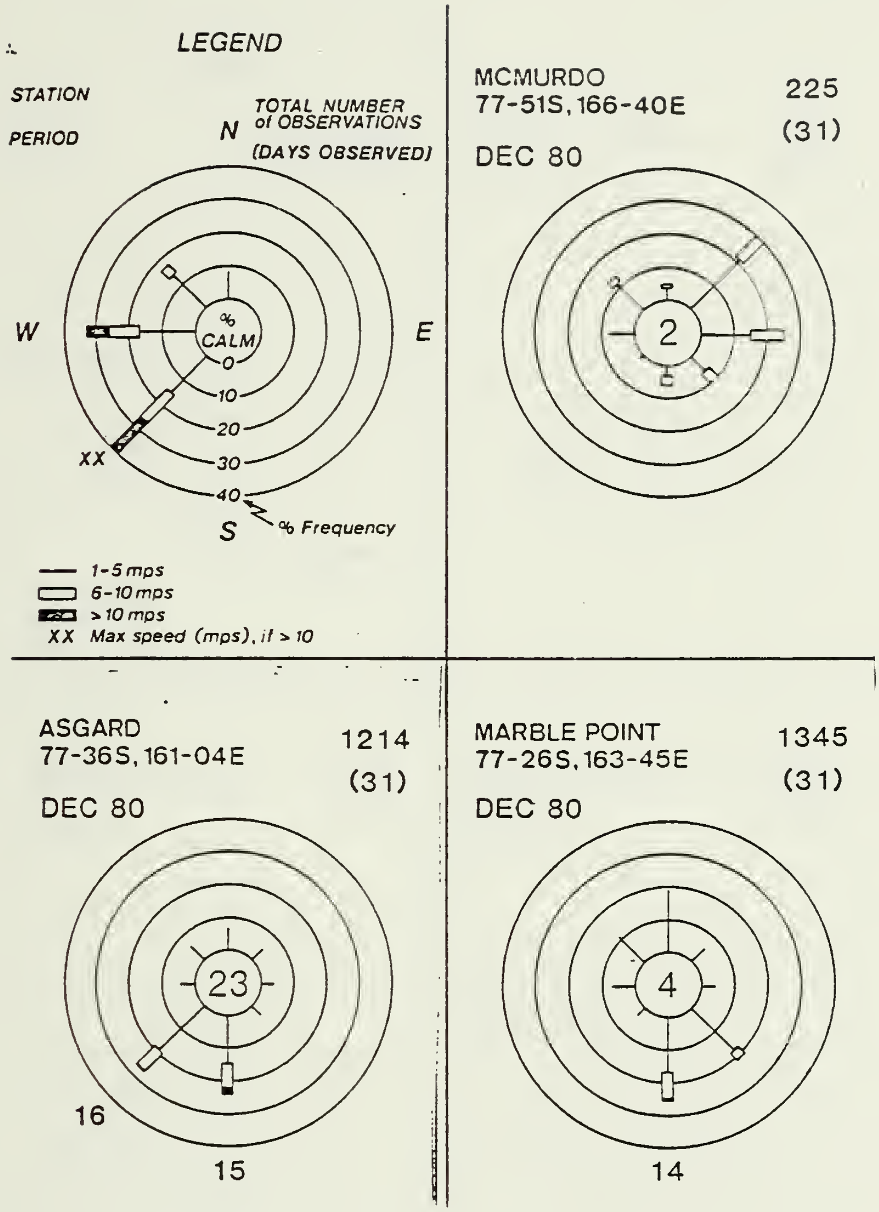


Figure 6. Surface Wind Roses for McMurdo, Asgard and Marble Point, December 1980

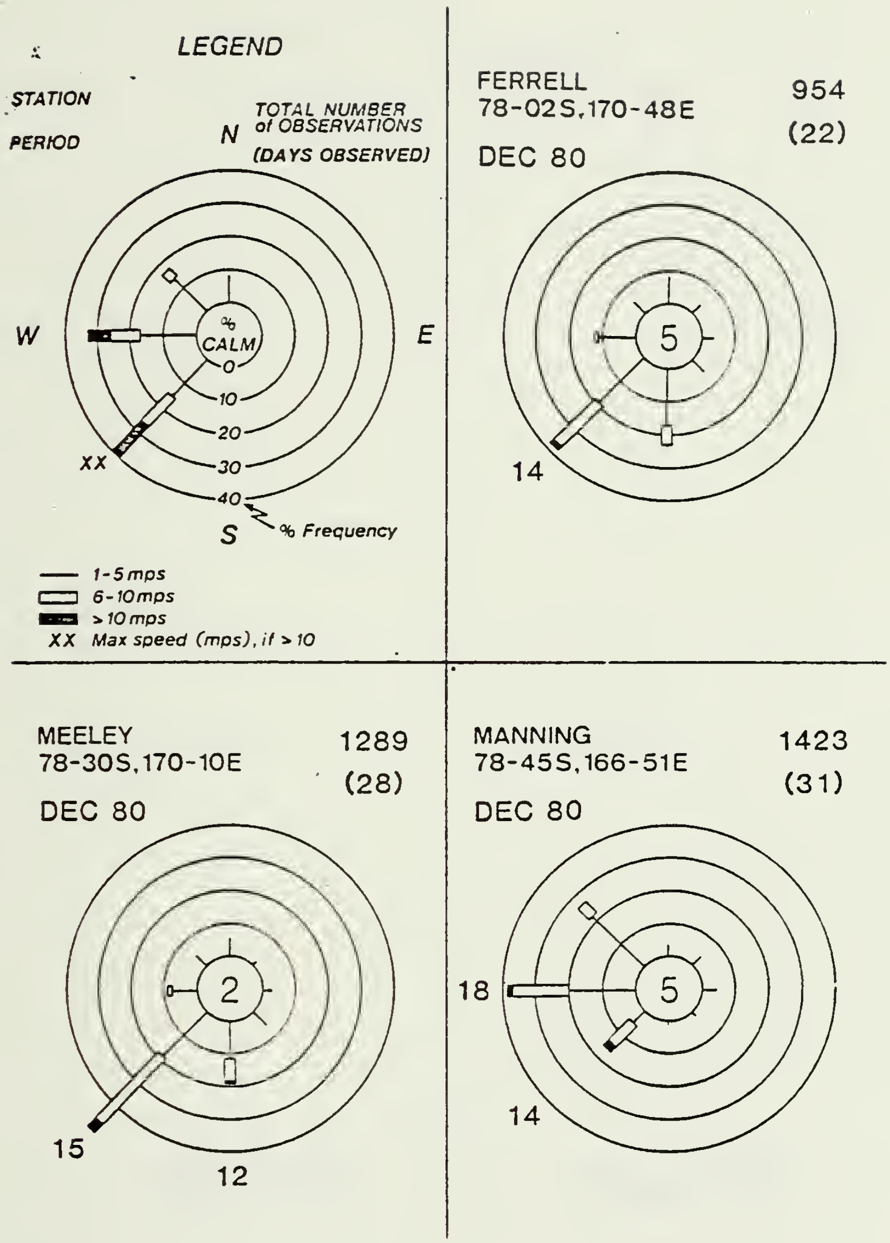


Figure 7. Surface Wind Roses for Ferrell, Meeley and Manning, December 1980

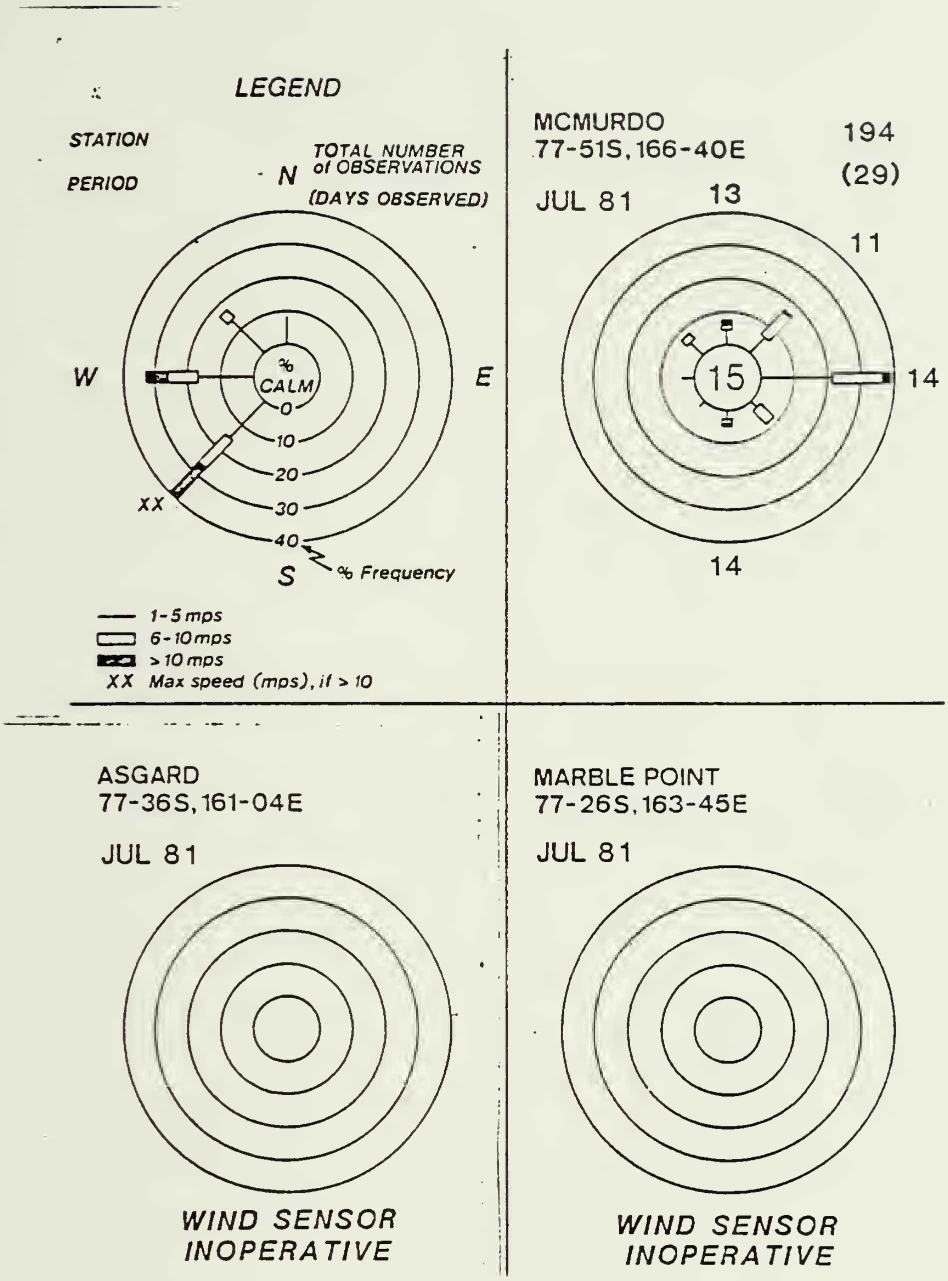


Figure 8. Surface Wind Roses for McMurdo, Asgard and Marble Point, July 1981

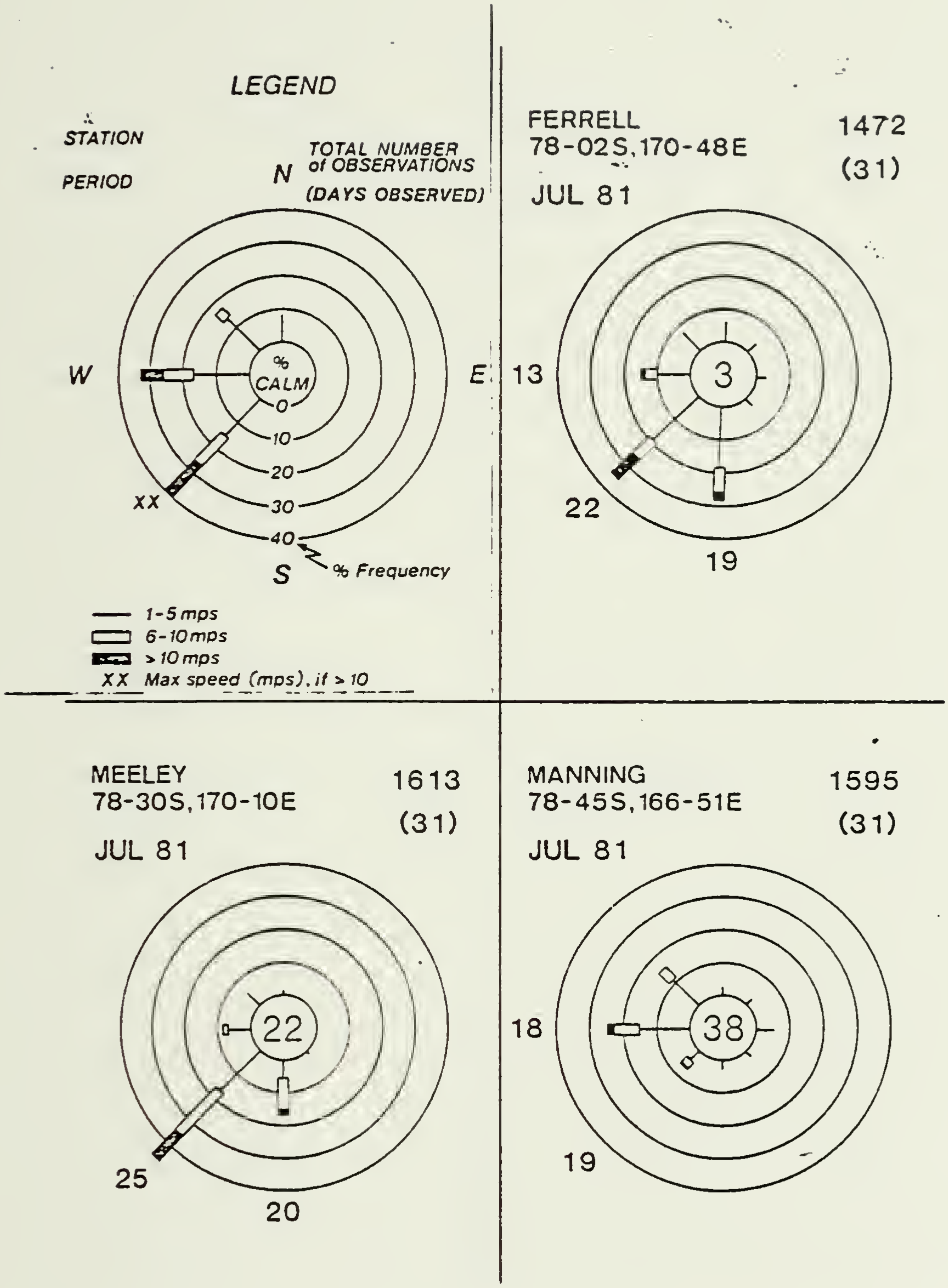


Figure 9. Surface Wind Roses for Ferrell, Meeley and Manning, July 1981

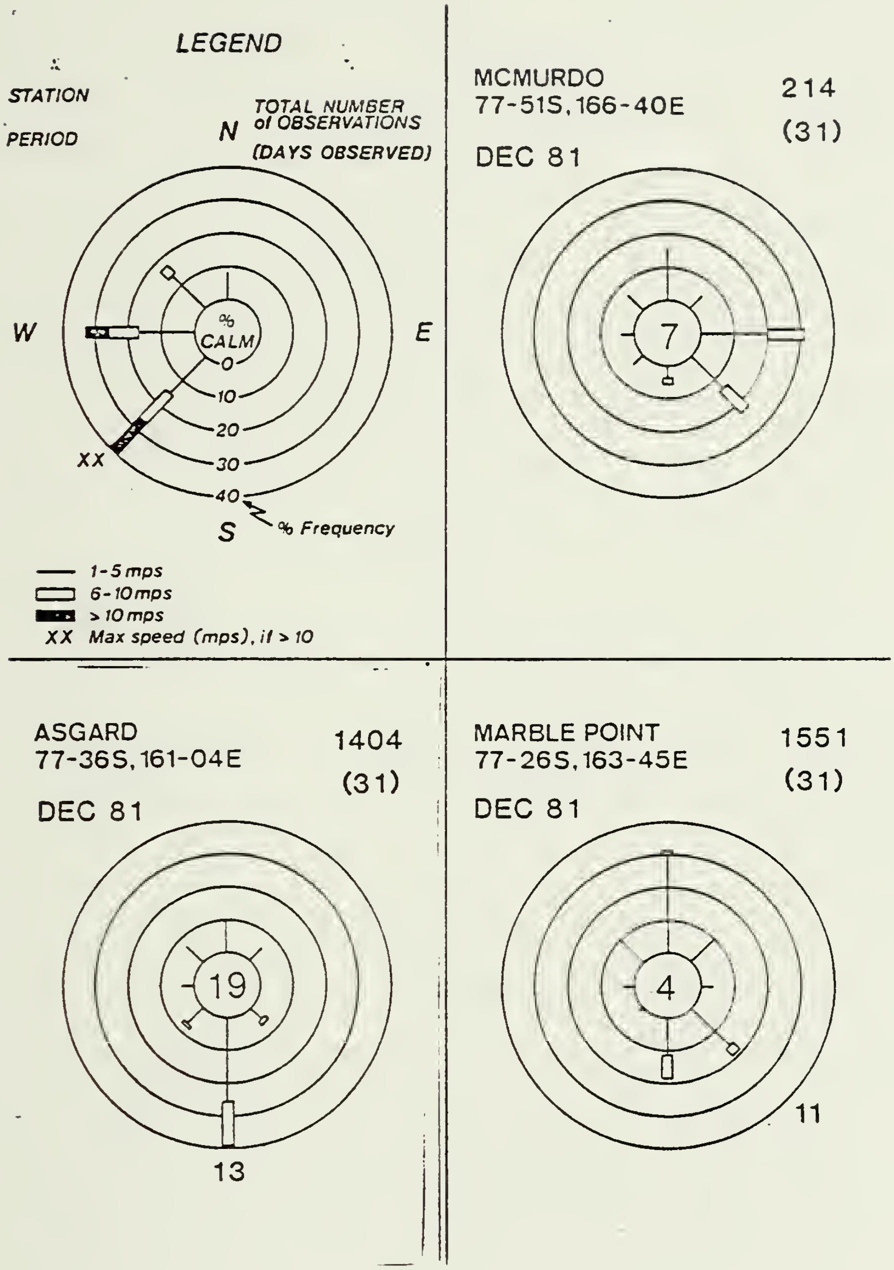


Figure 10. Surface Wind Roses for McMurdo, Asgard and Marble Point, December 1981

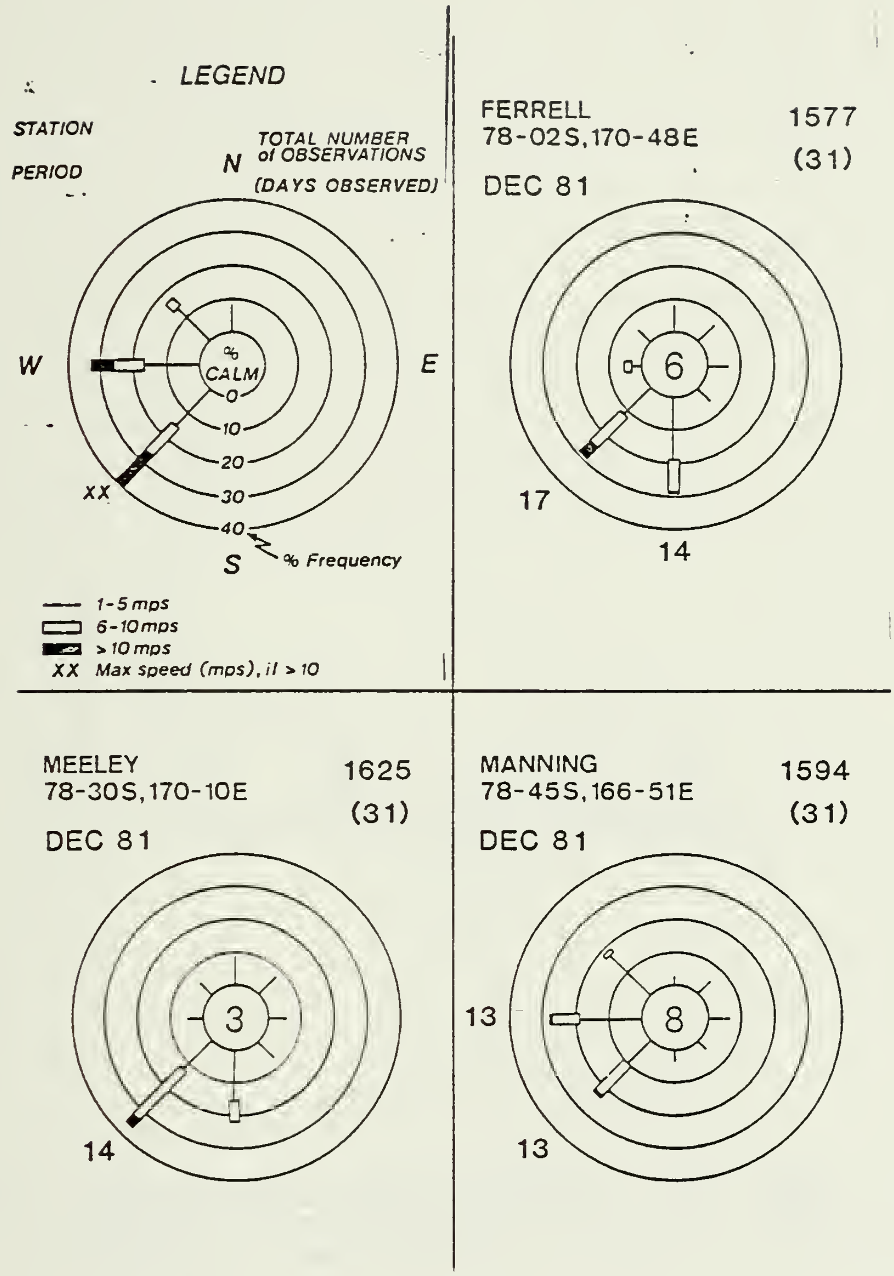


Figure 11. Surface Wind Roses for Ferrell, Meeley and Manning, December 1981

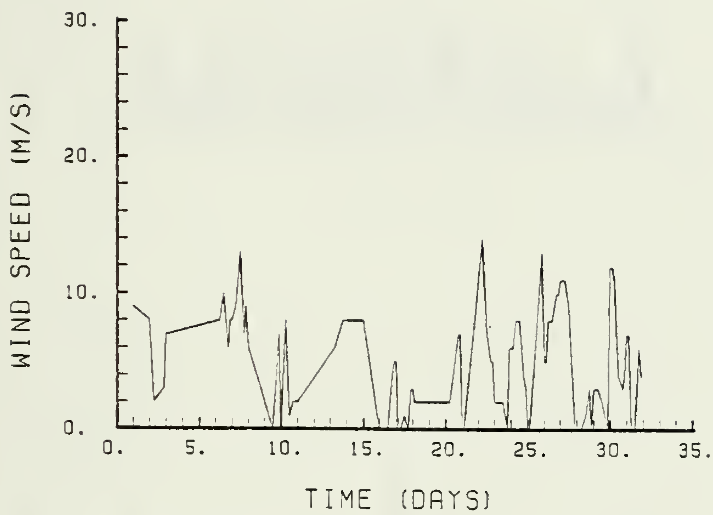
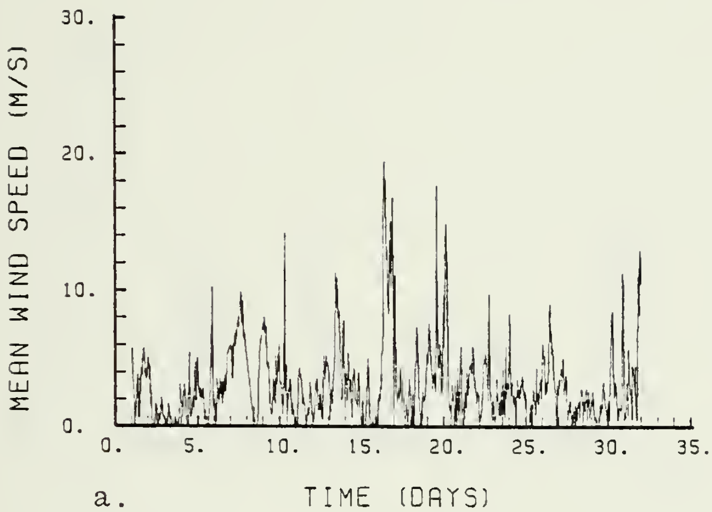
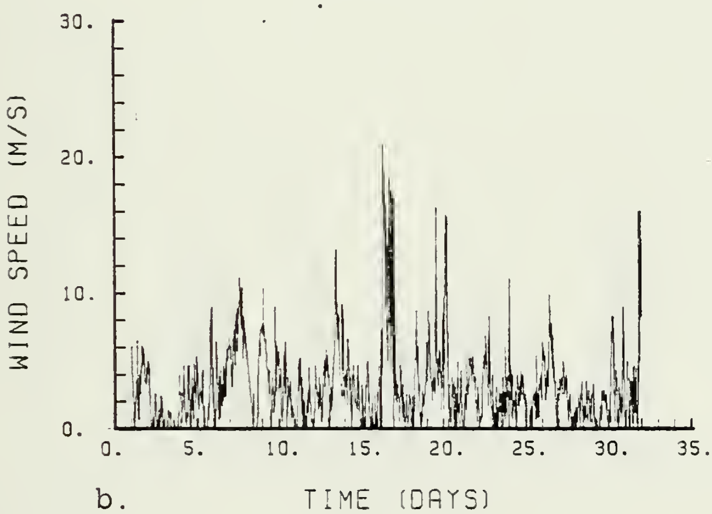


Figure 12. Surface Wind Speed, McMurdo, July 1980 (observations at six-h intervals; some data missing. See Table VI).



a.



b.

Figure 13a. Mean Surface Wind Speed, Marble Point, July 1980.

13b. Surface Wind Speed, Marble Point, July 1980.

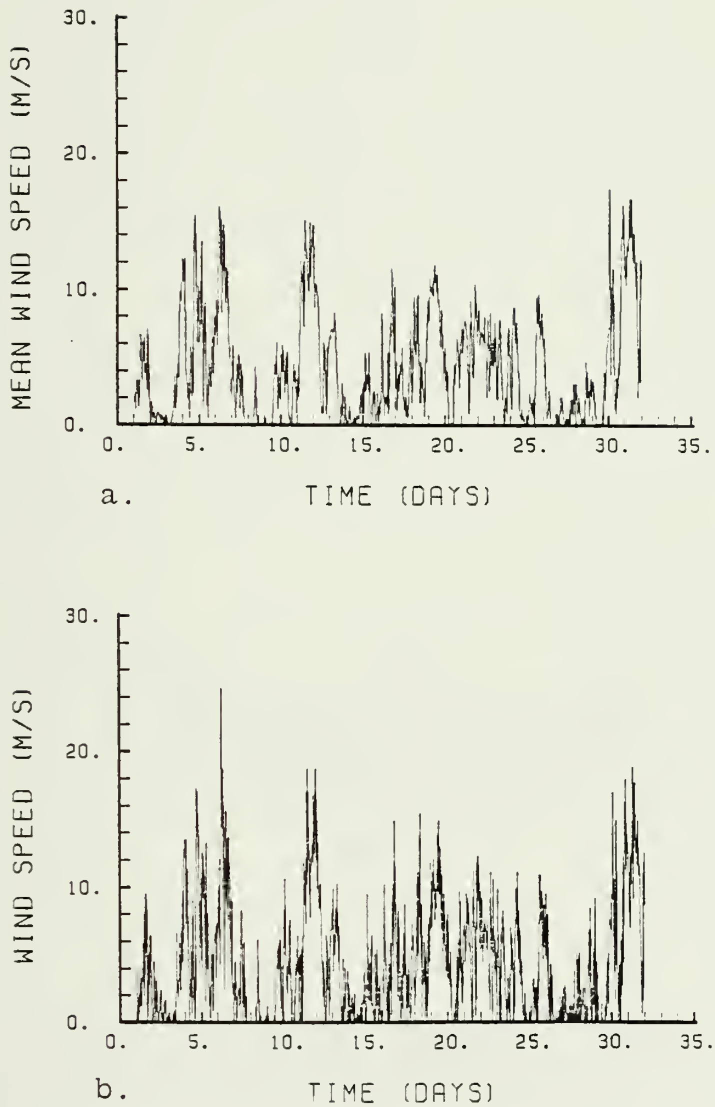


Figure 14a. Mean Surface Wind Speed, Asgard, July 1980
14b. Surface Wind Speed, Asgard, July 1980

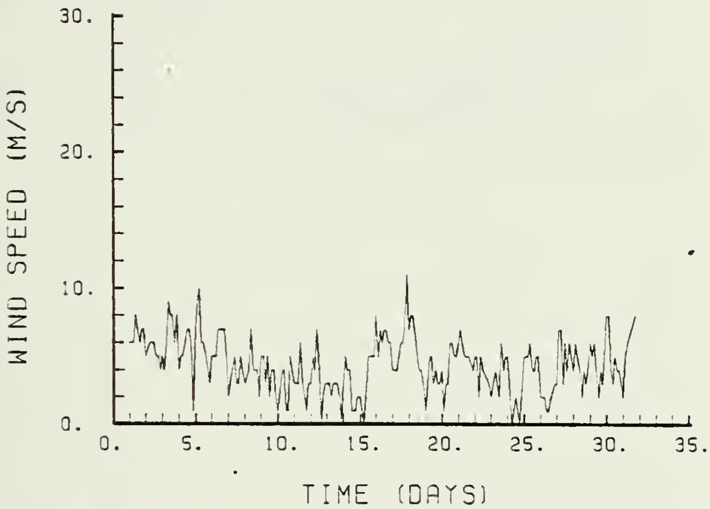


Figure 15. Surface Wind Speed, McMurdo, December 1980 (observations at three-h interval, some data missing. See Table VI).

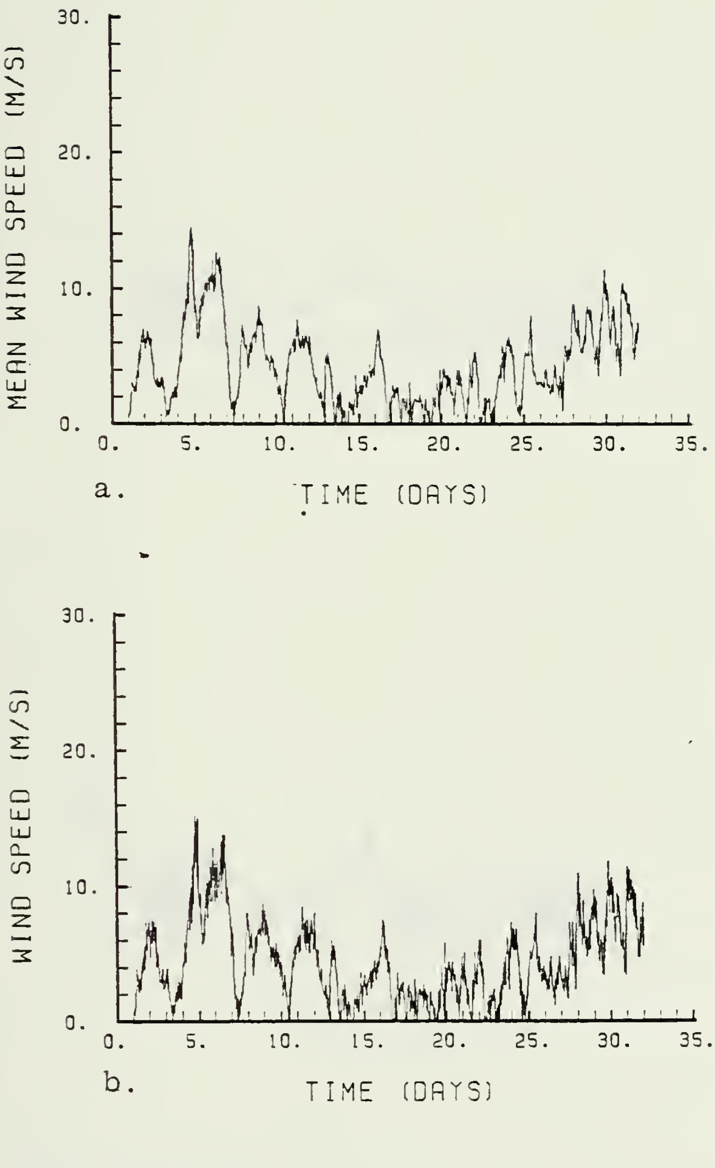
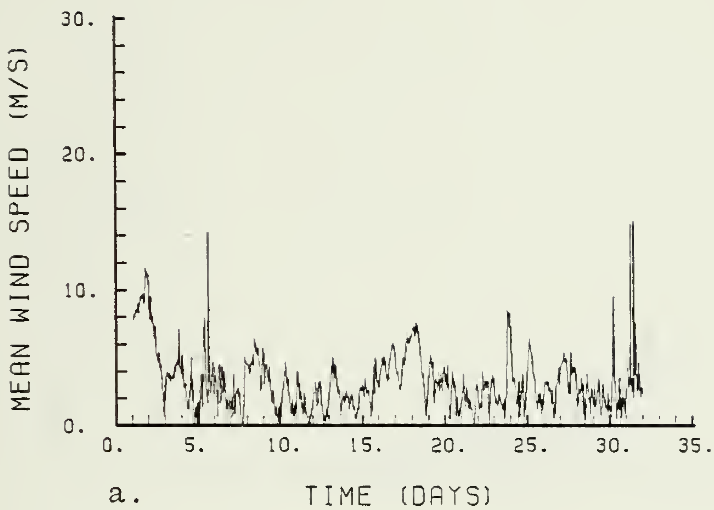
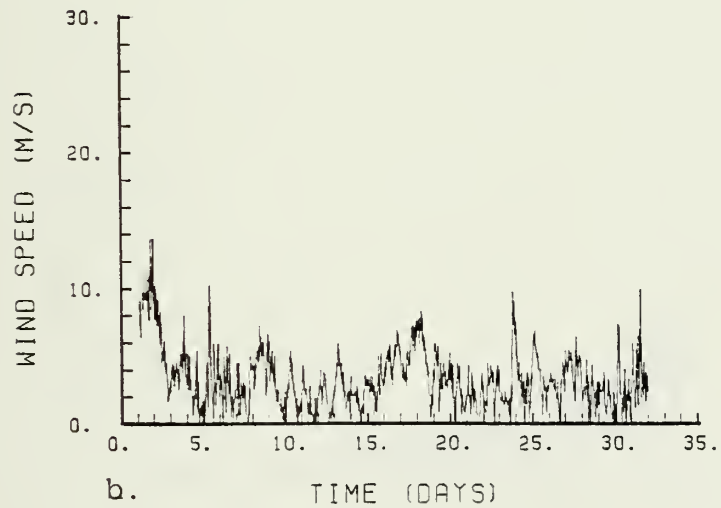


Figure 16a. Mean Surface Wind Speed, Manning, December 1980.
16b. Surface Wind Speed, Manning, December 1980.



a.



b.

Figure 17a. Mean Surface Wind Speed, Marble Point, December 1980.
17b. Surface Wind Speed, Marble Point, December 1980.

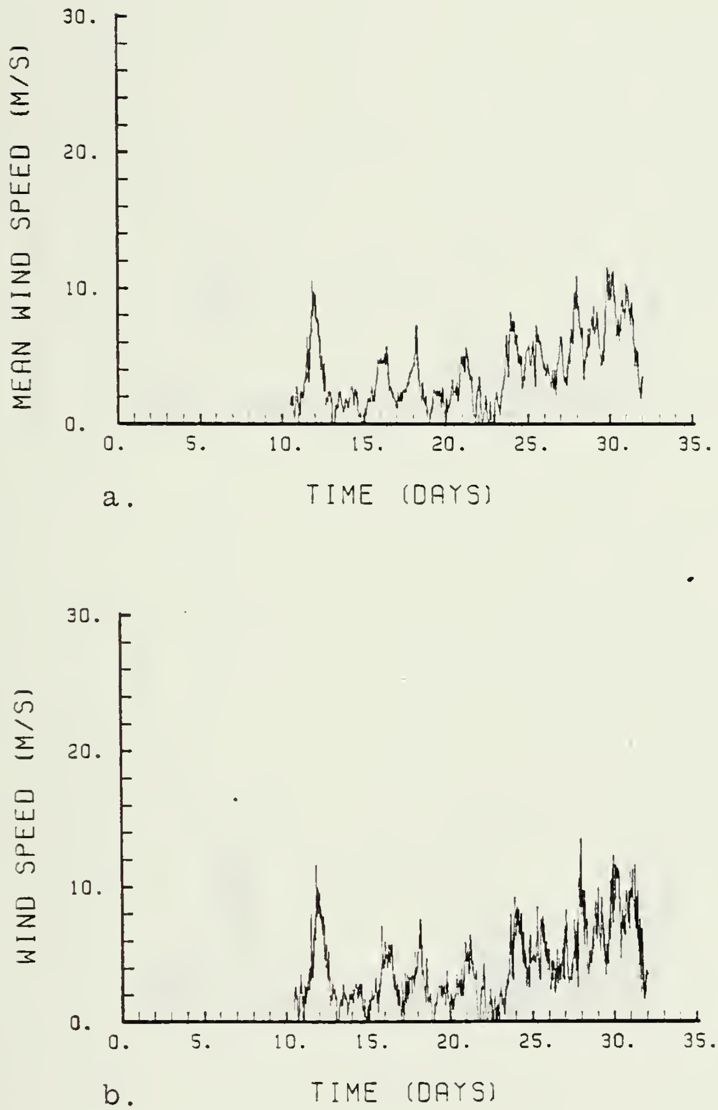


Figure 18a. Mean Surface Wind Speed, Ferrell, December 1980.
18b. Surface Wind Speed, Ferrell, December 1980.

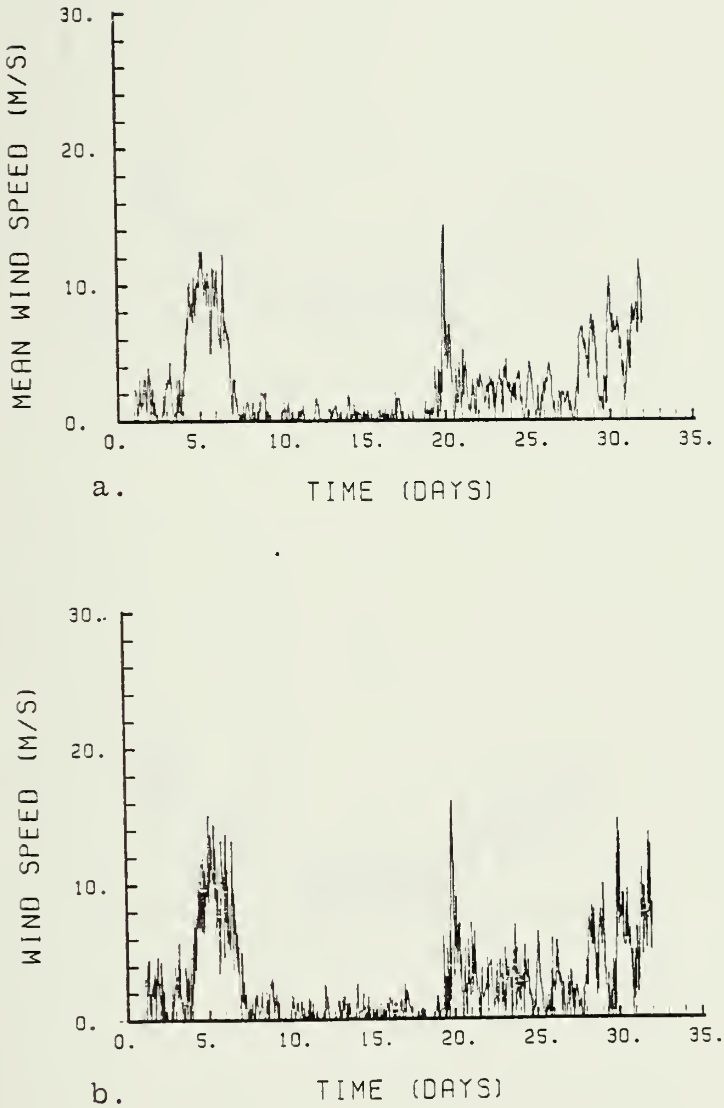


Figure 19a. Mean Surface Wind Speed, Asgard, December 1980.
19b. Surface Wind Speed, Asgard, December 1980.

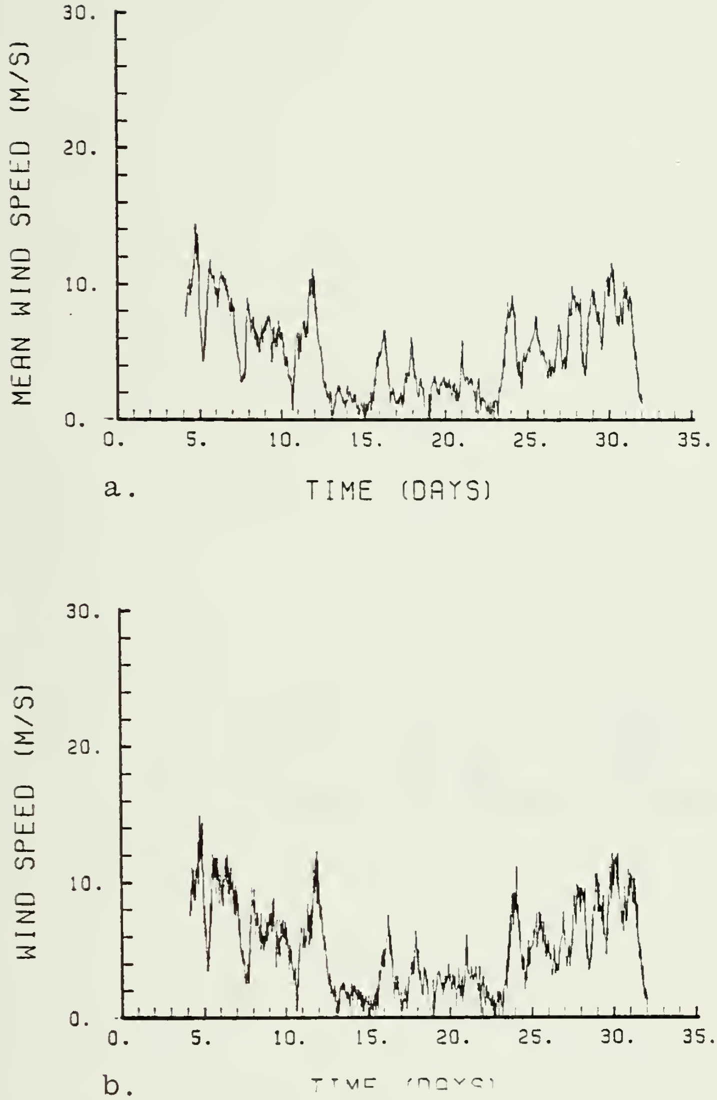


Figure 20a. Mean Surface Wind Speed, Meeley, December 1980.
20b. Surface Wind Speed, Meeley, December 1980.

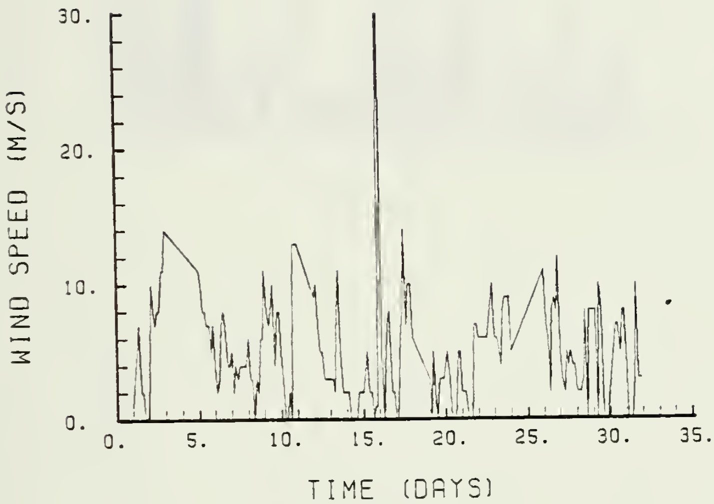


Figure 21. Surface Wind Speed, McMurdo, July 1981 (observations at six-h intervals; some data missing. See Table VI).

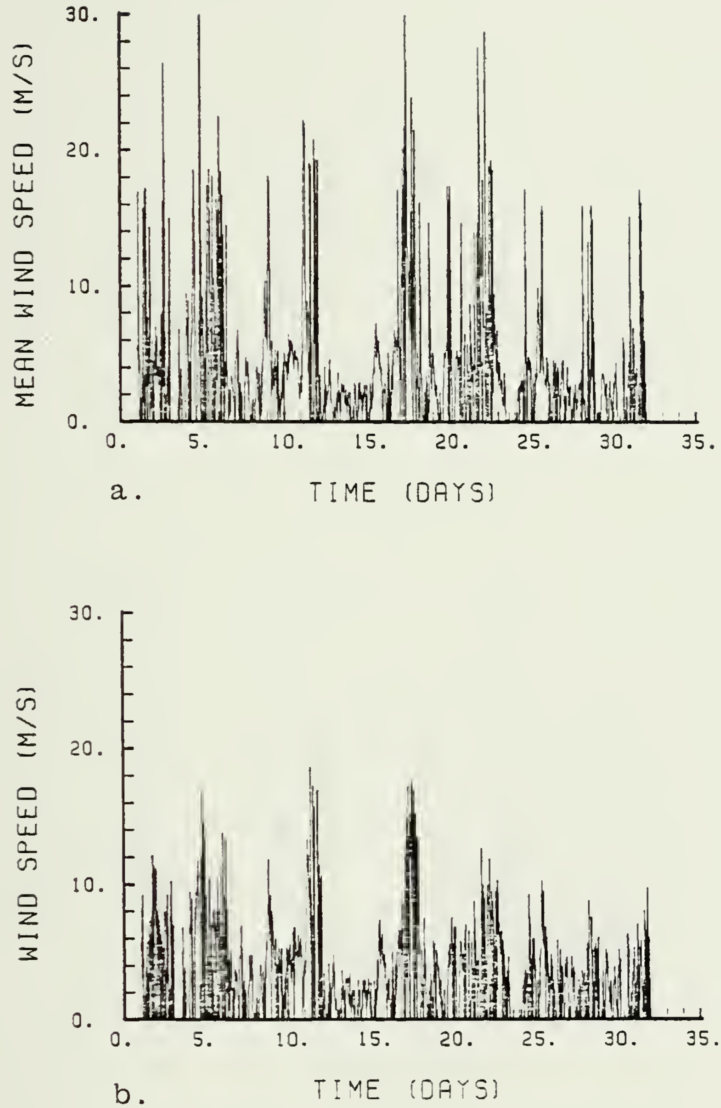


Figure 22a. Mean Surface Wind Speed, Manning, July 1981
22b. Surface Wind Speed, Manning, July 1981

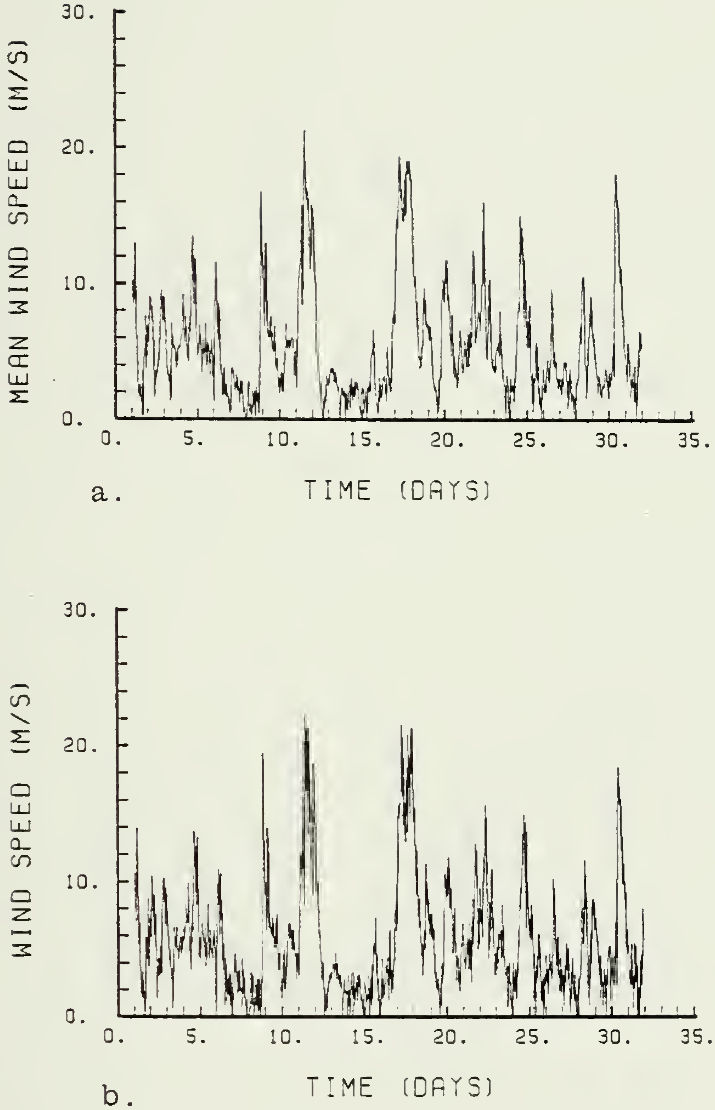


Figure 23a. Mean Surface Wind Speed, Ferrell, July 1981
23b. Surface Wind Speed, Ferrell, July 1981

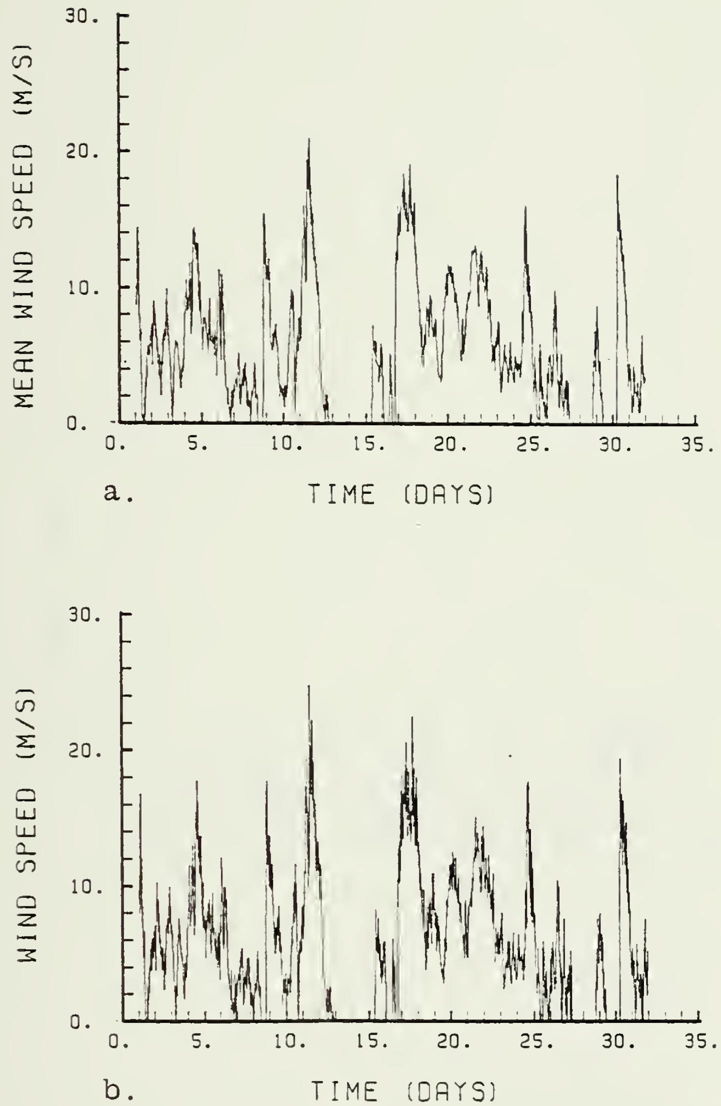


Figure 24a. Mean Surface Wind Speed, Meeley, July 1981
24b. Surface Wind Speed, Meeley, July 1981

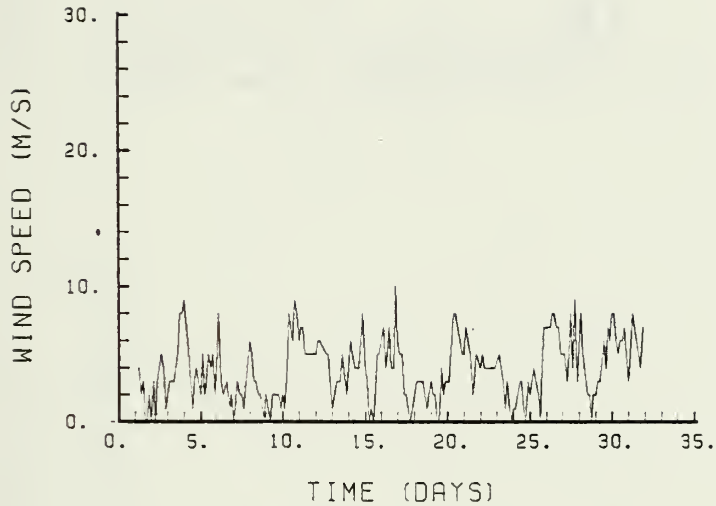
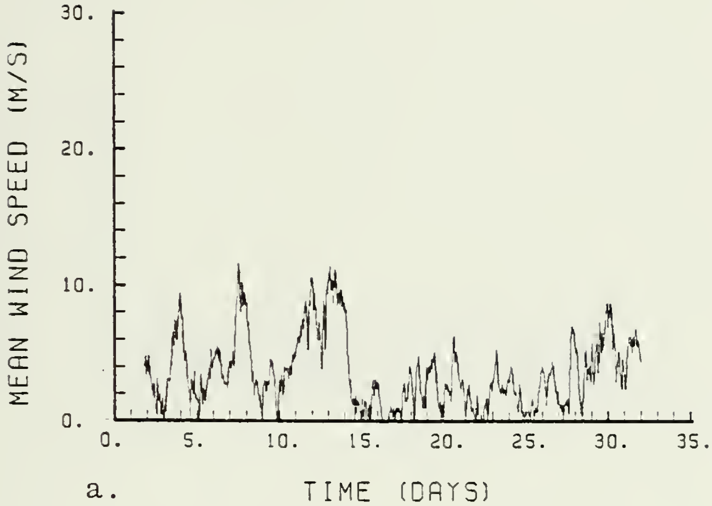
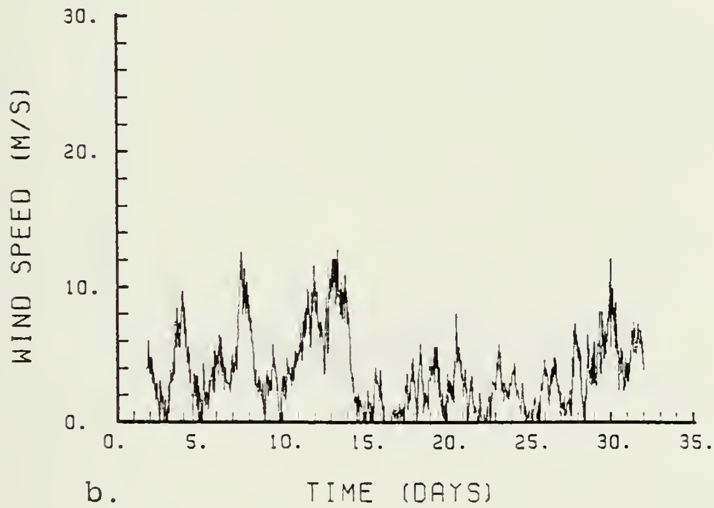


Figure 25. Surface Wind Speed, McMurdo, December 1981 (observations at three-h interval, some data missing. See Table VI).

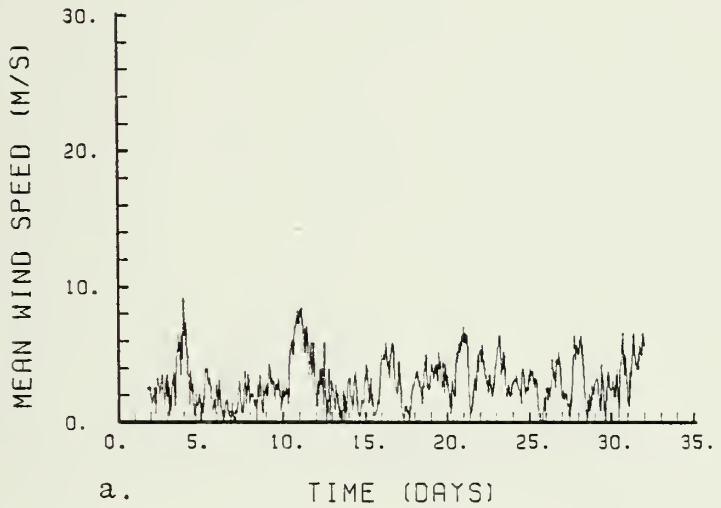


a.



b.

Figure 26a. Mean Surface Wind Speed, Manning, December 1981.
26b. Surface Wind Speed, Manning, December 1981.



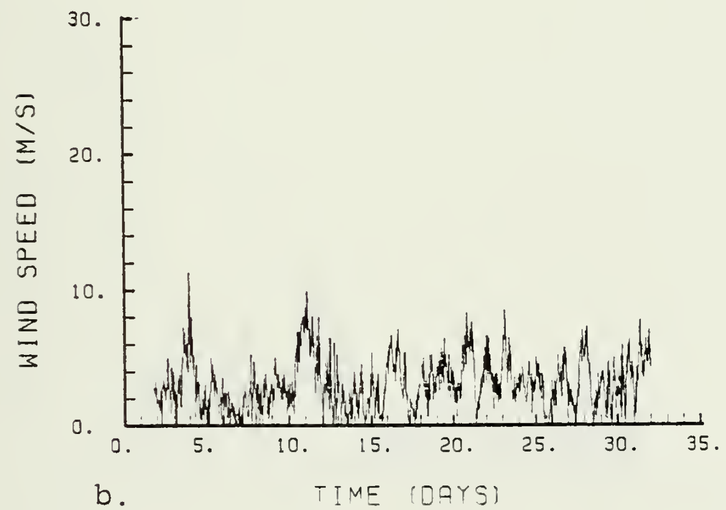
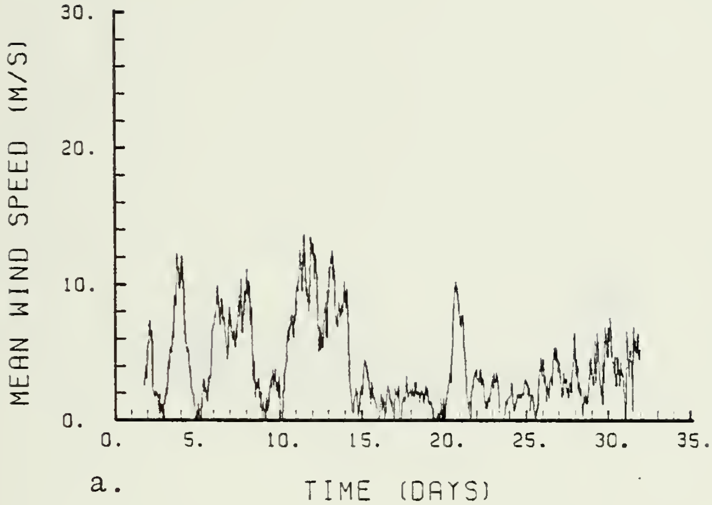
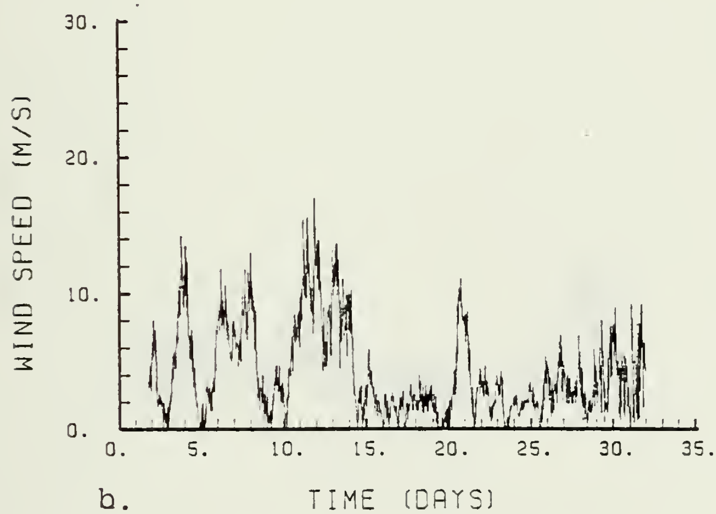


Figure 27a. Mean Surface Wind Speed, Marble Point, December 1981.

27b. Surface Wind Speed, Marble Point, December 1981.



a.



b.

Figure 28a. Mean Surface Wind Speed, Ferrell, December 1981.
28b. Surface Wind Speed, Ferrell, December 1981.

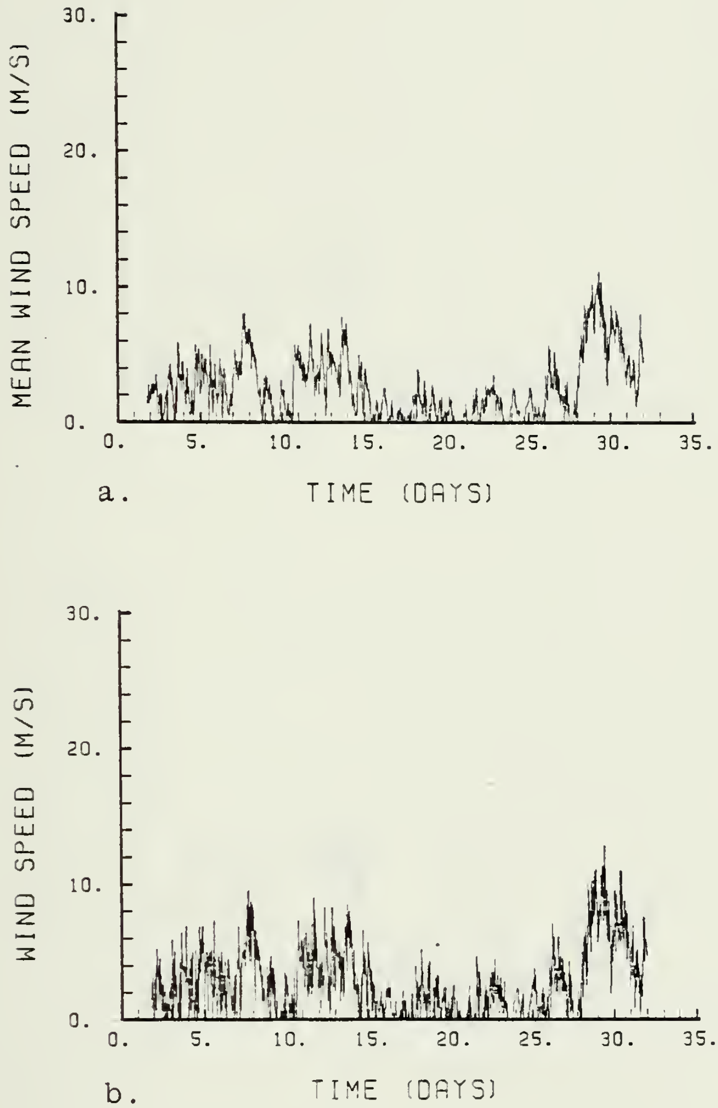


Figure 29a. Mean Surface Wind Speed, Asgard, December 1981.
29b. Surface Wind Speed, Asgard, December 1981.

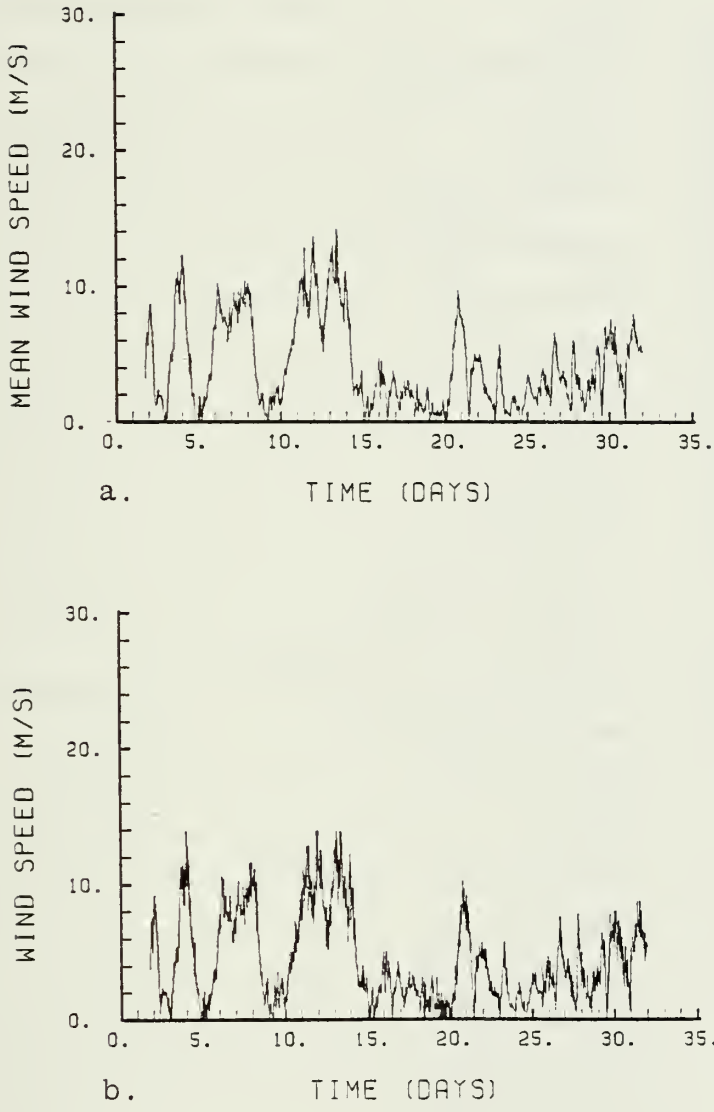


Figure 30a. Mean Surface Wind Speed, Meeley, December 1981
b. Surface Wind Speed, Meeley, December 1981

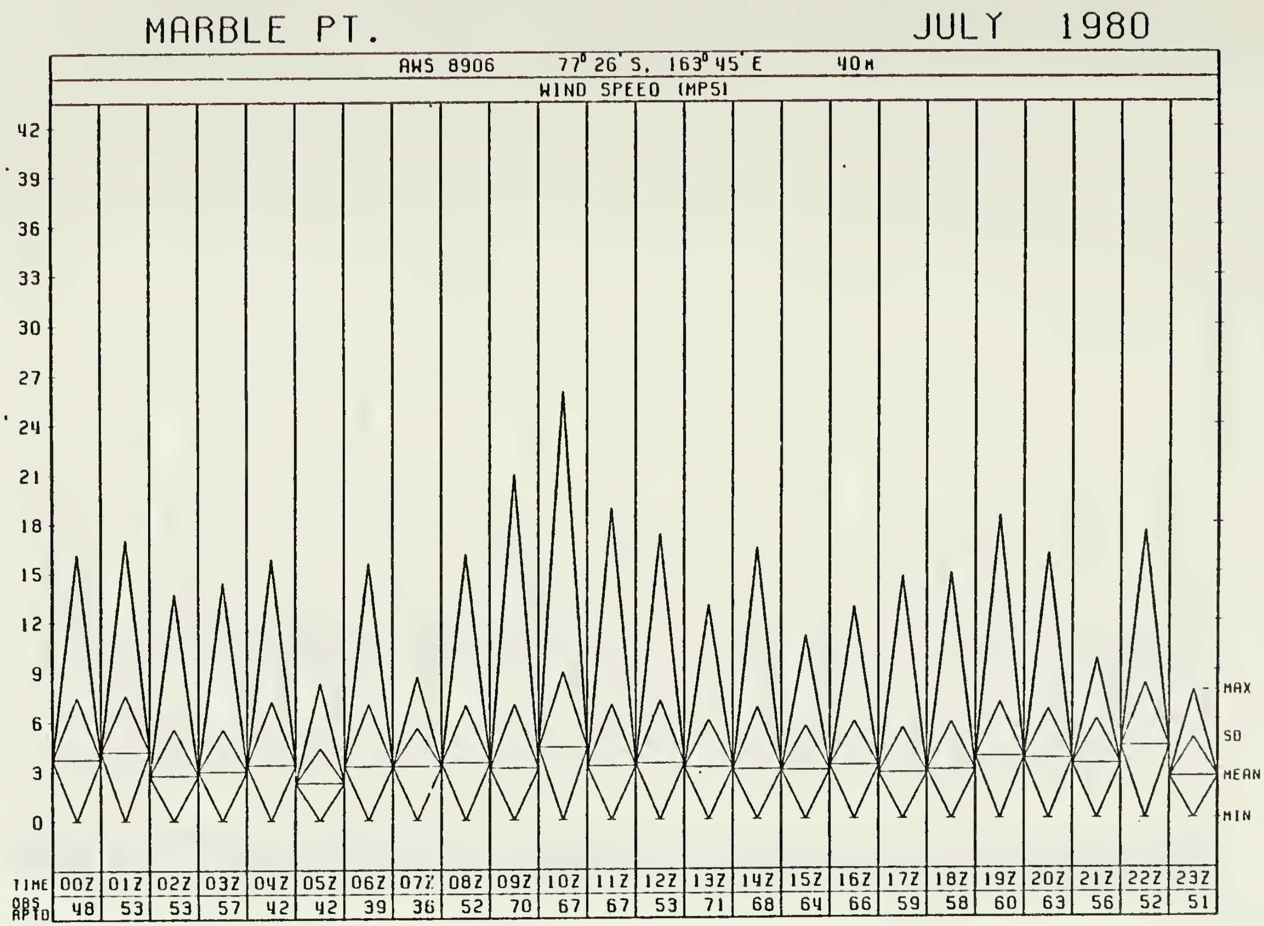


Figure 31. Diurnal Surface Wind Speed, Marble Point, July 1980

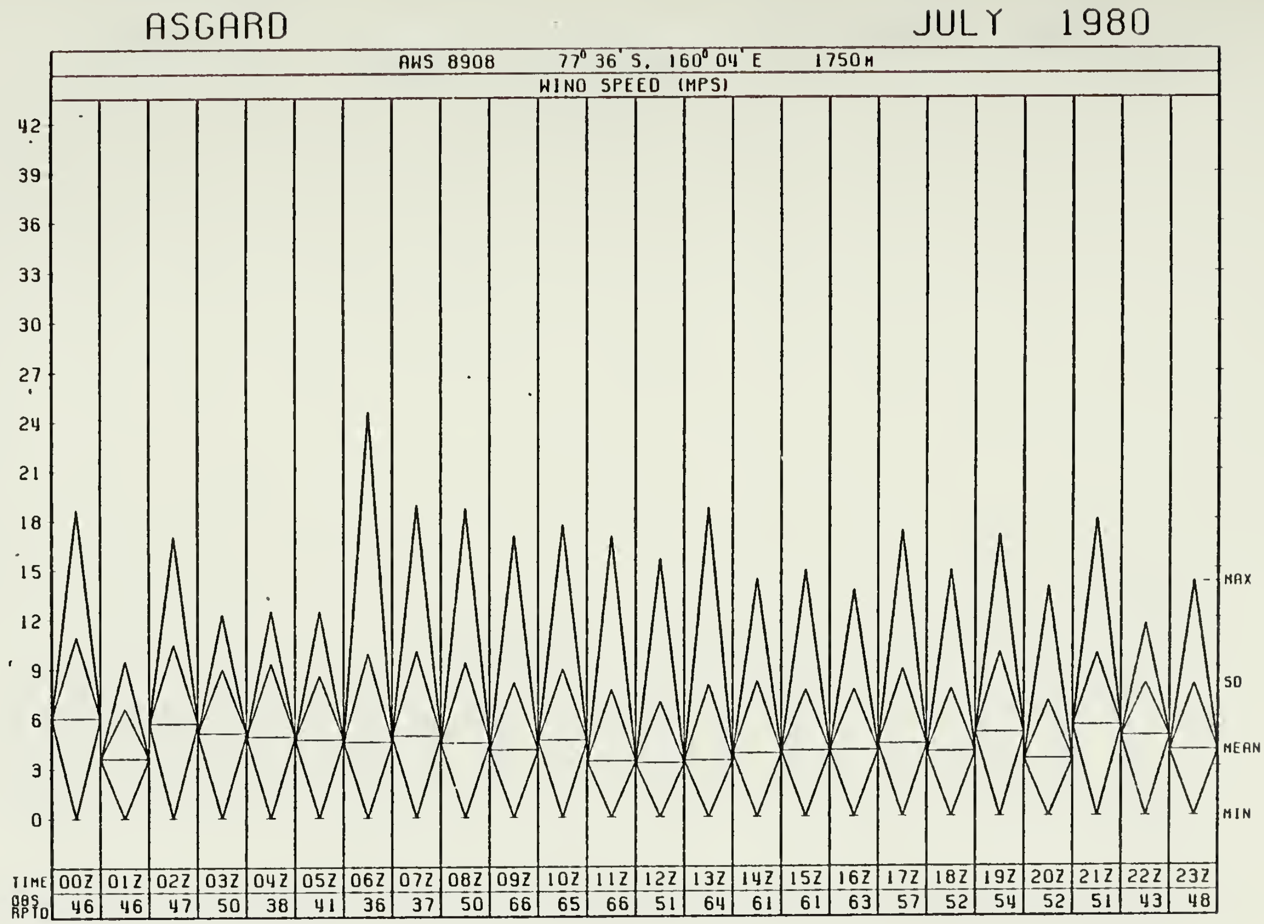


Figure 32. Diurnal Surface Wind Speed, Asgard, July 1980

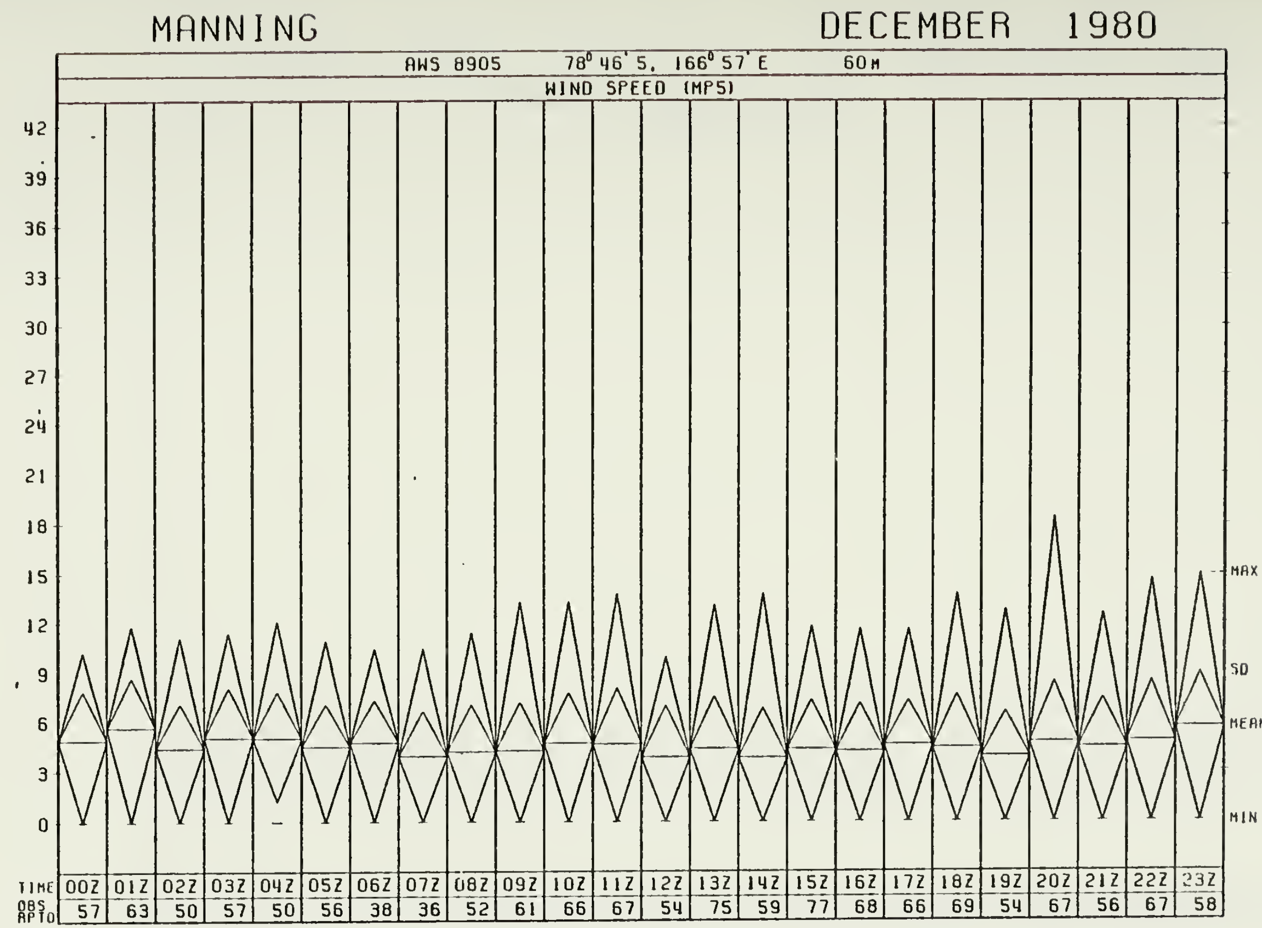


Figure 33. Diurnal Surface Wind Speed, Manning, December 1980

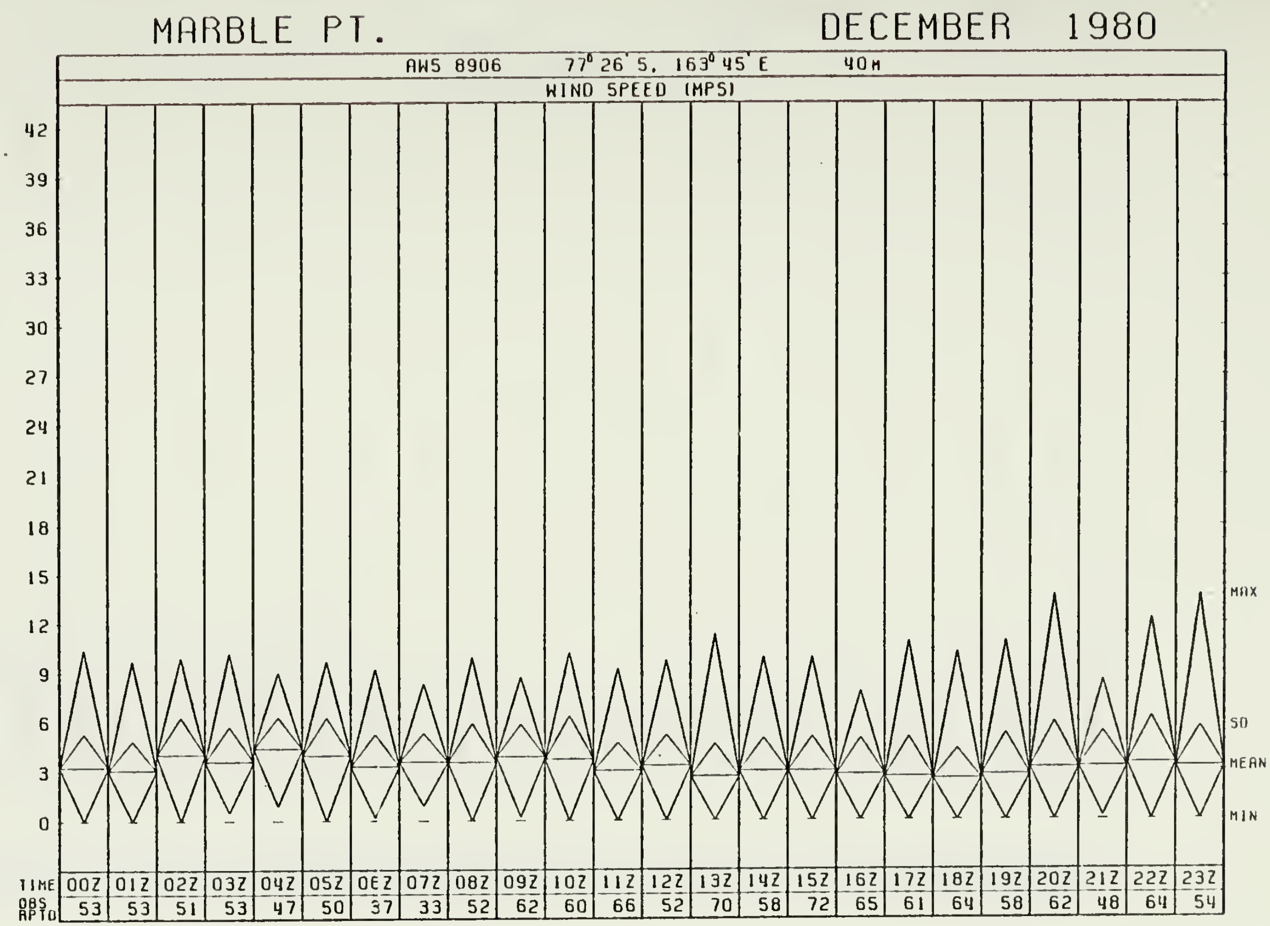


Figure 34. Diurnal Surface Wind Speed, Marble Point, December 1980

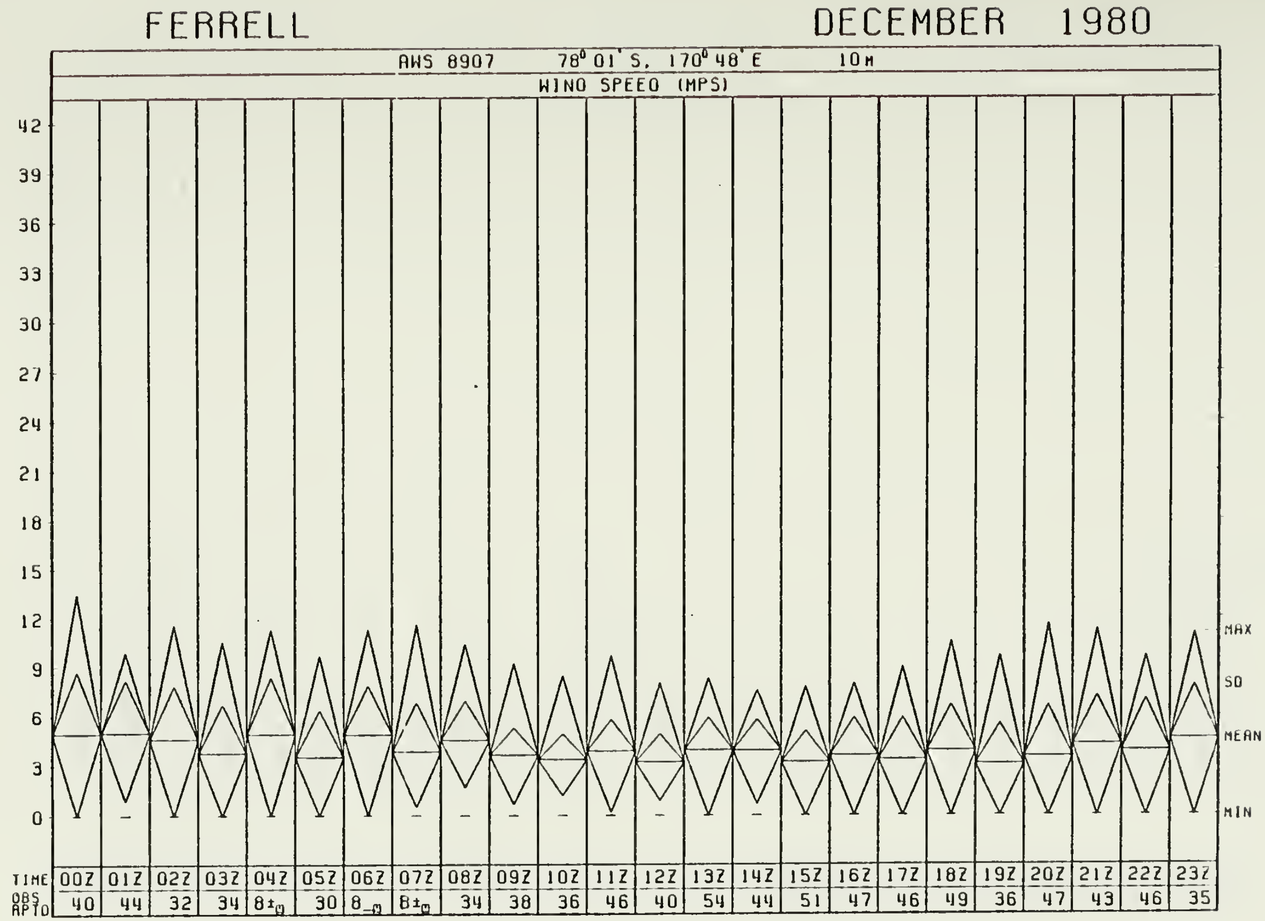


Figure 35. Diurnal Surface Wind Speed, Ferrell, December 1980

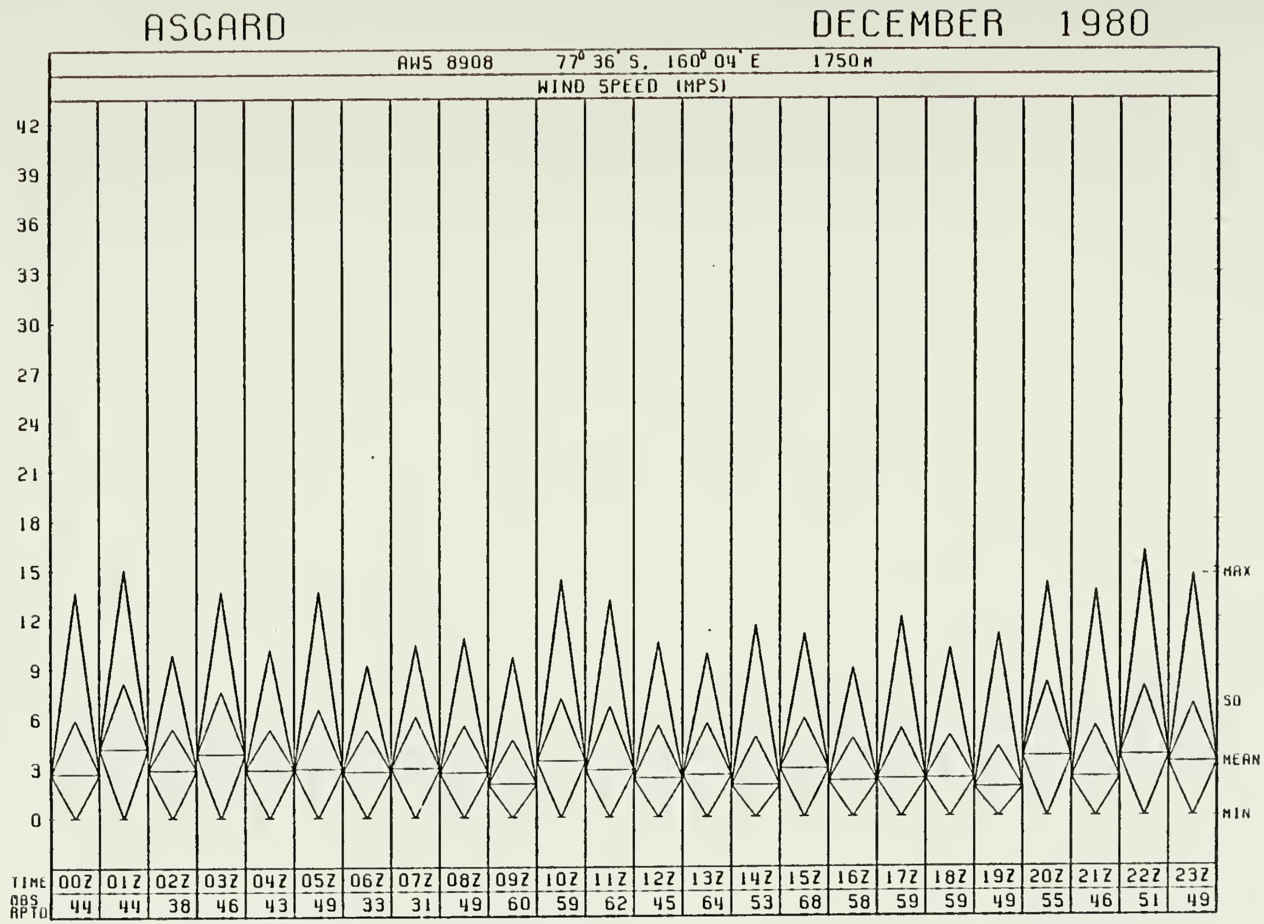


Figure 36. Diurnal Surface Wind Speed, Asgard, December 1980

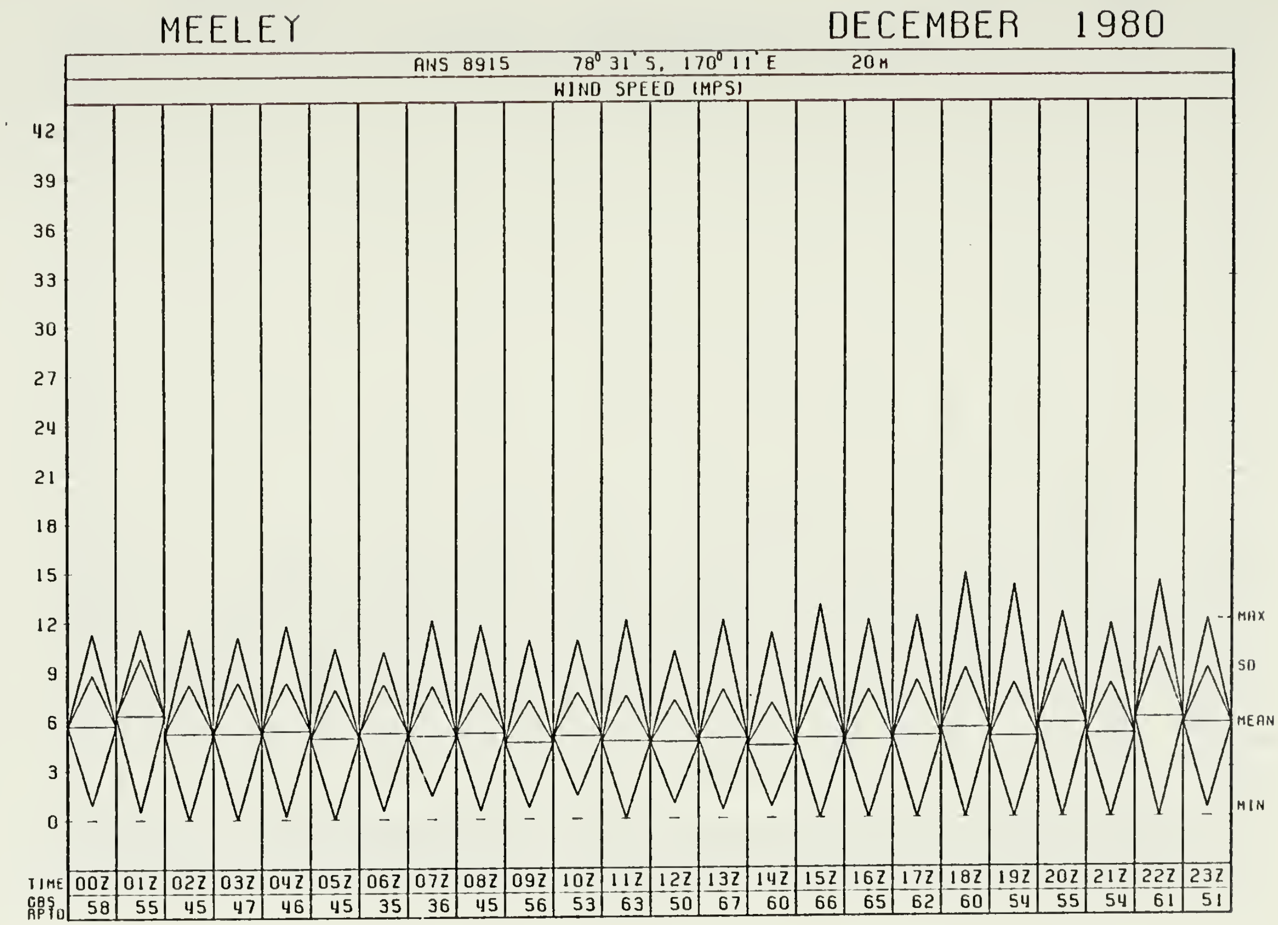


Figure 37. Diurnal Surface Wind Speed, Meeley, December 1980

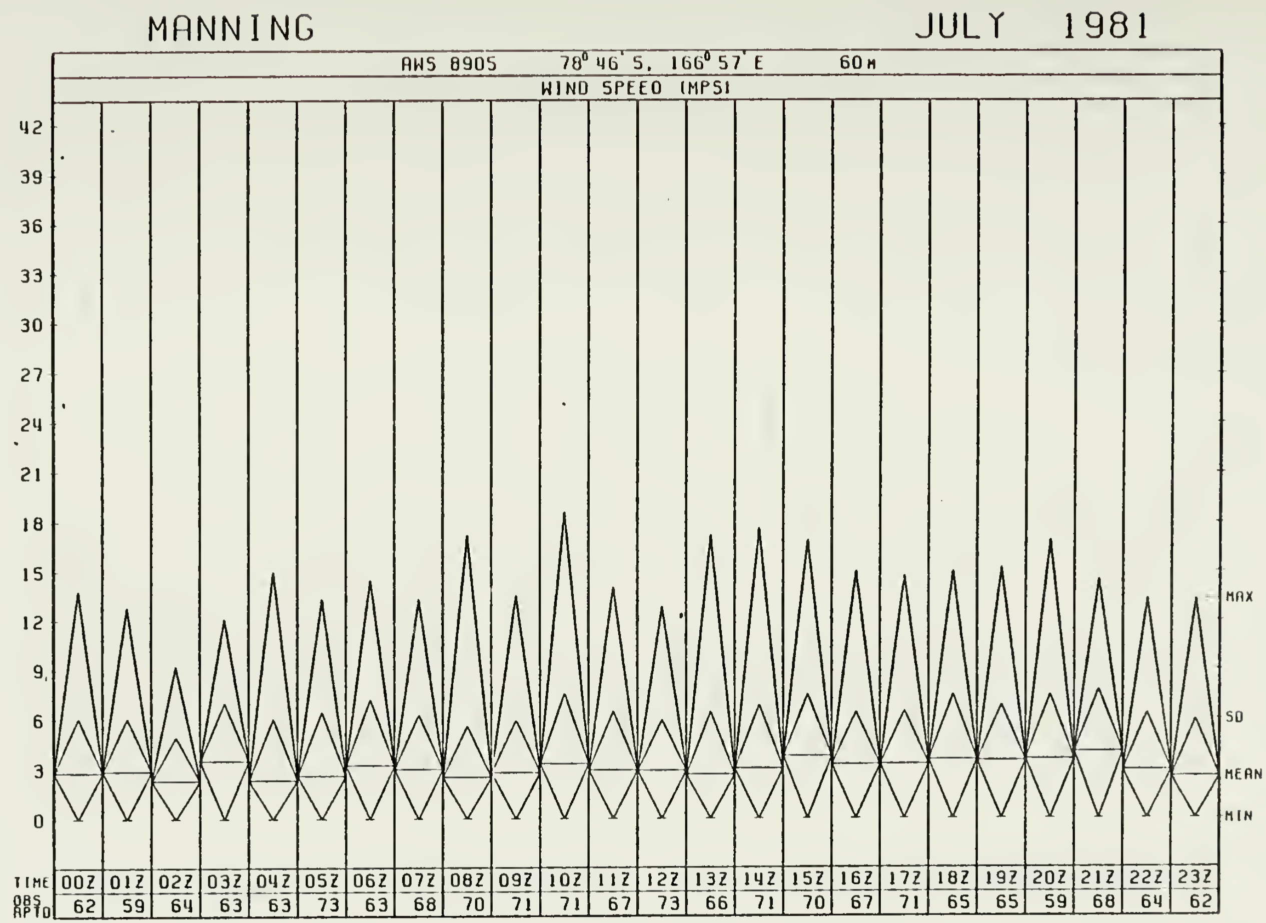


Figure 38. Diurnal Surface Wind Speed, Manning, July 1981

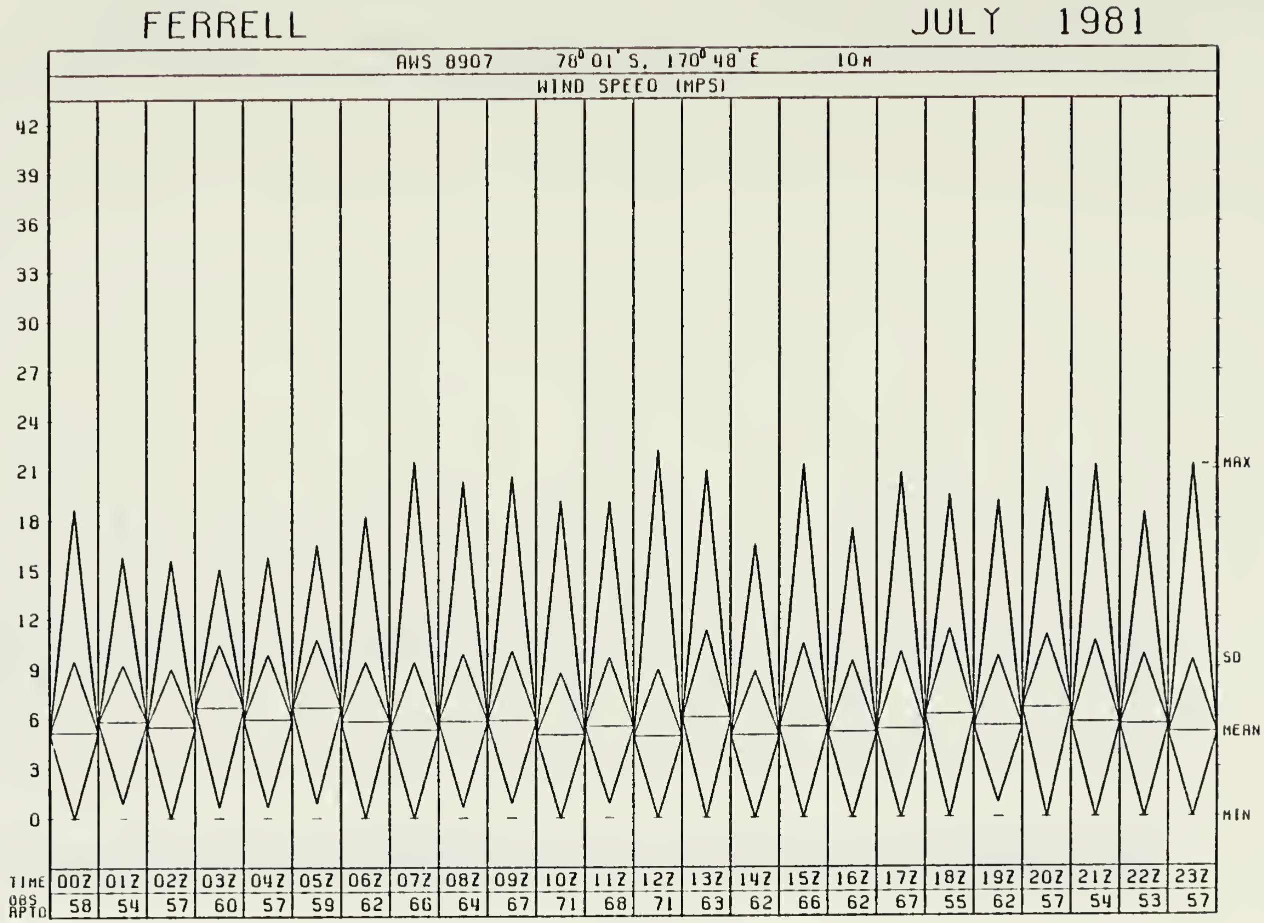


Figure 39. Diurnal Surface Wind Speed, Ferrell, July 1981

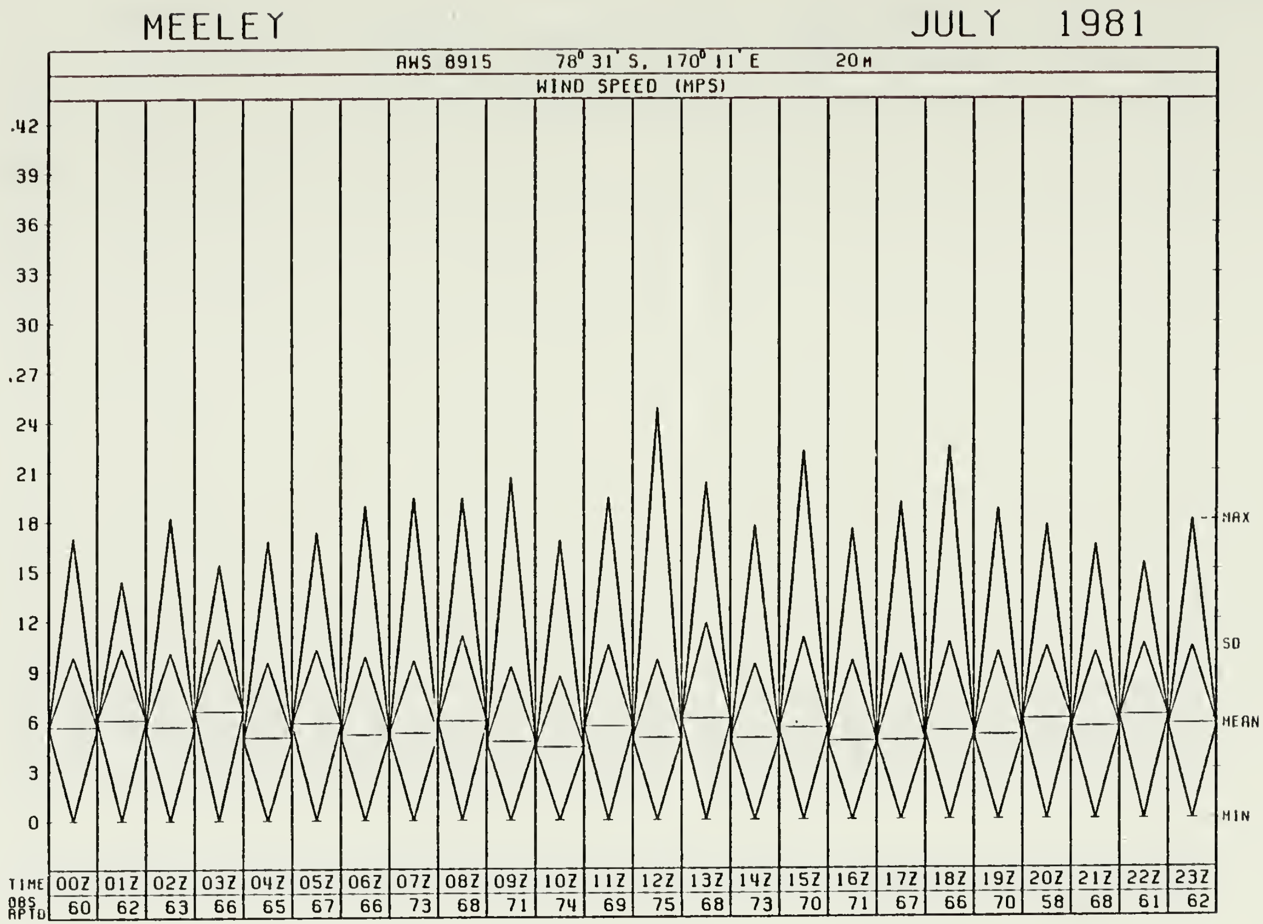


Figure 40. Diurnal Surface Wind Speed, Meeley, July 1981

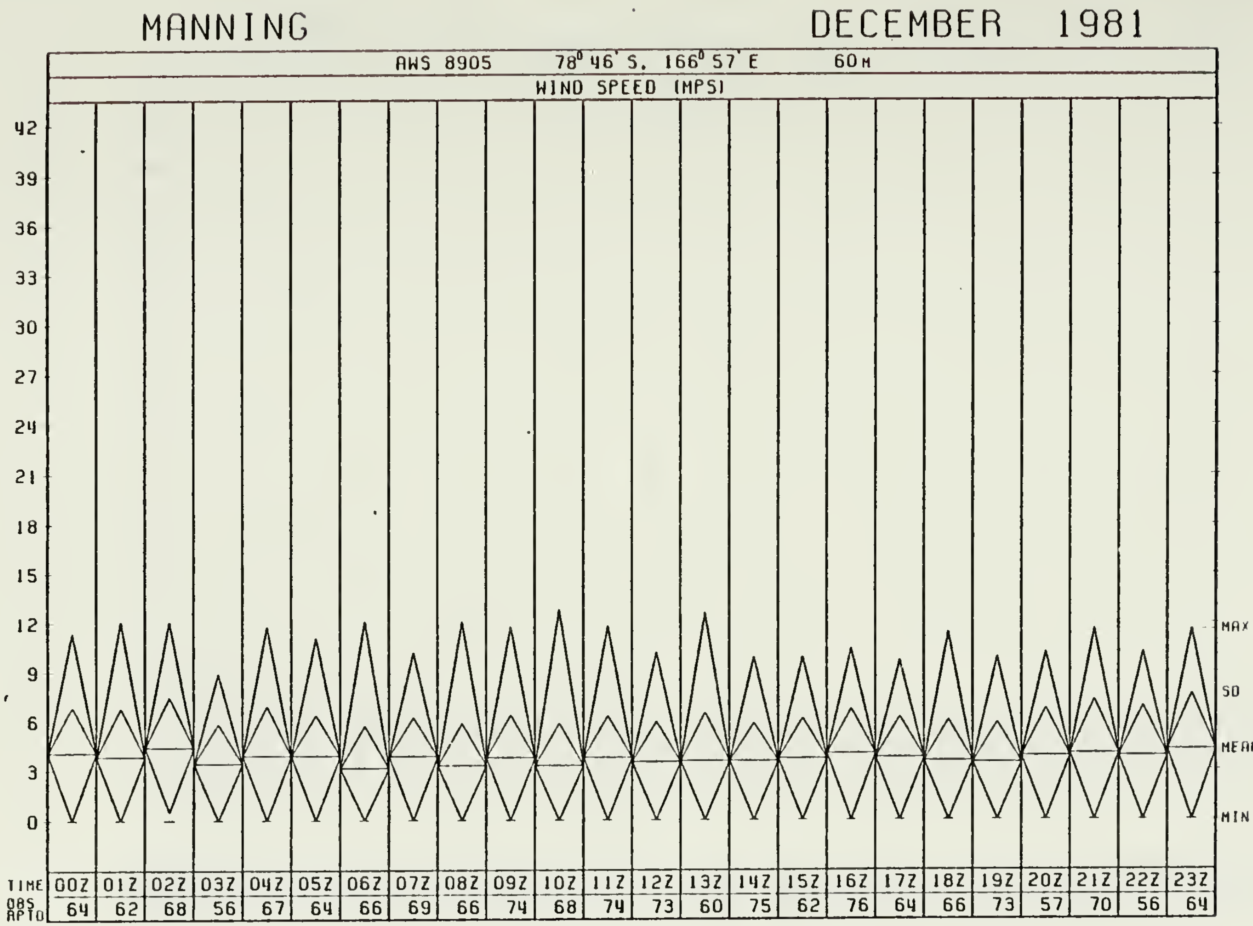


Figure 41. Diurnal Surface Wind Speed, Manning, December 1981

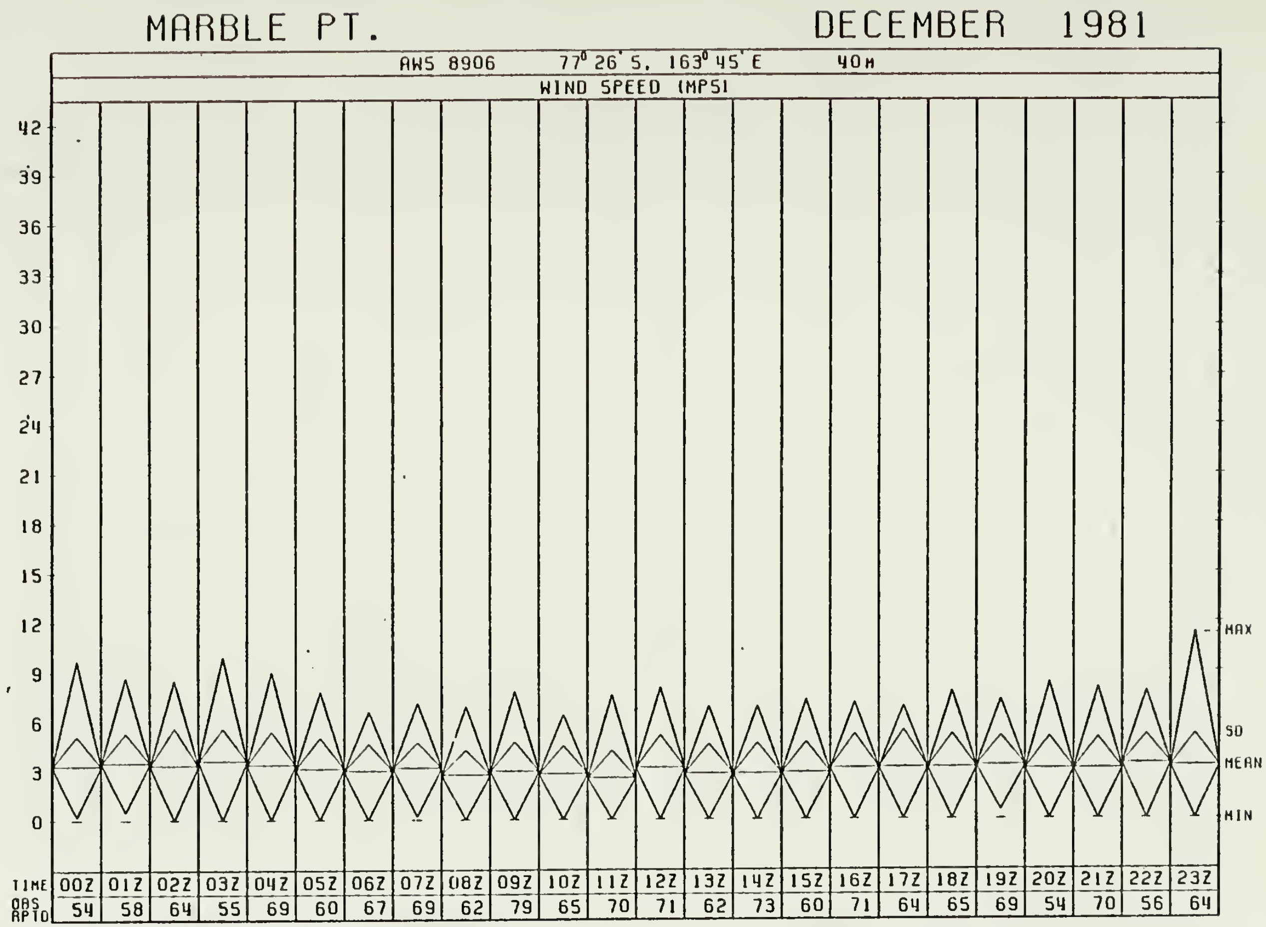


Figure 42. Diurnal Surface Wind Speed, Marble Point, December 1981

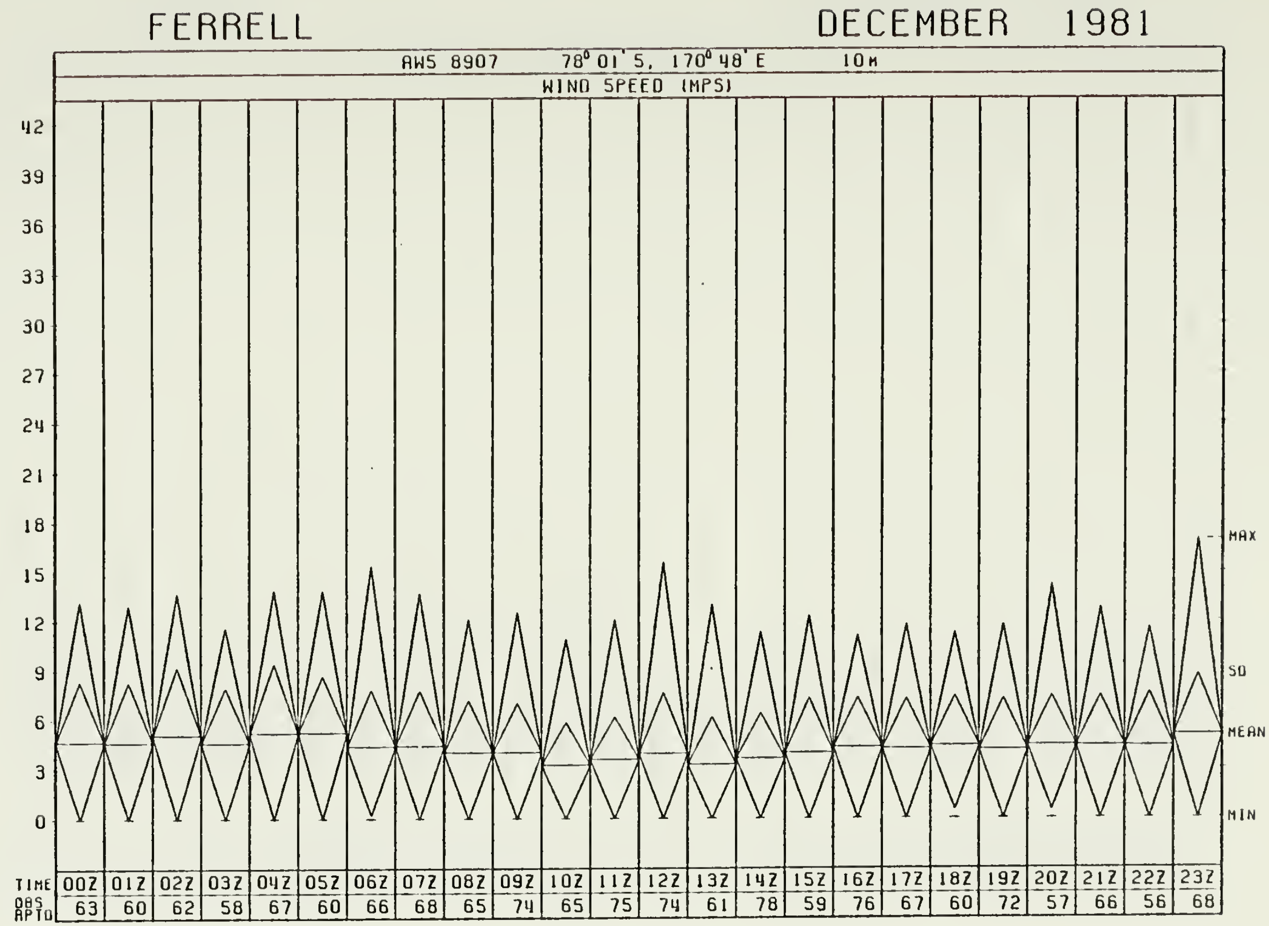


Figure 43. Diurnal Surface Wind Speed, Ferrell, December 1981

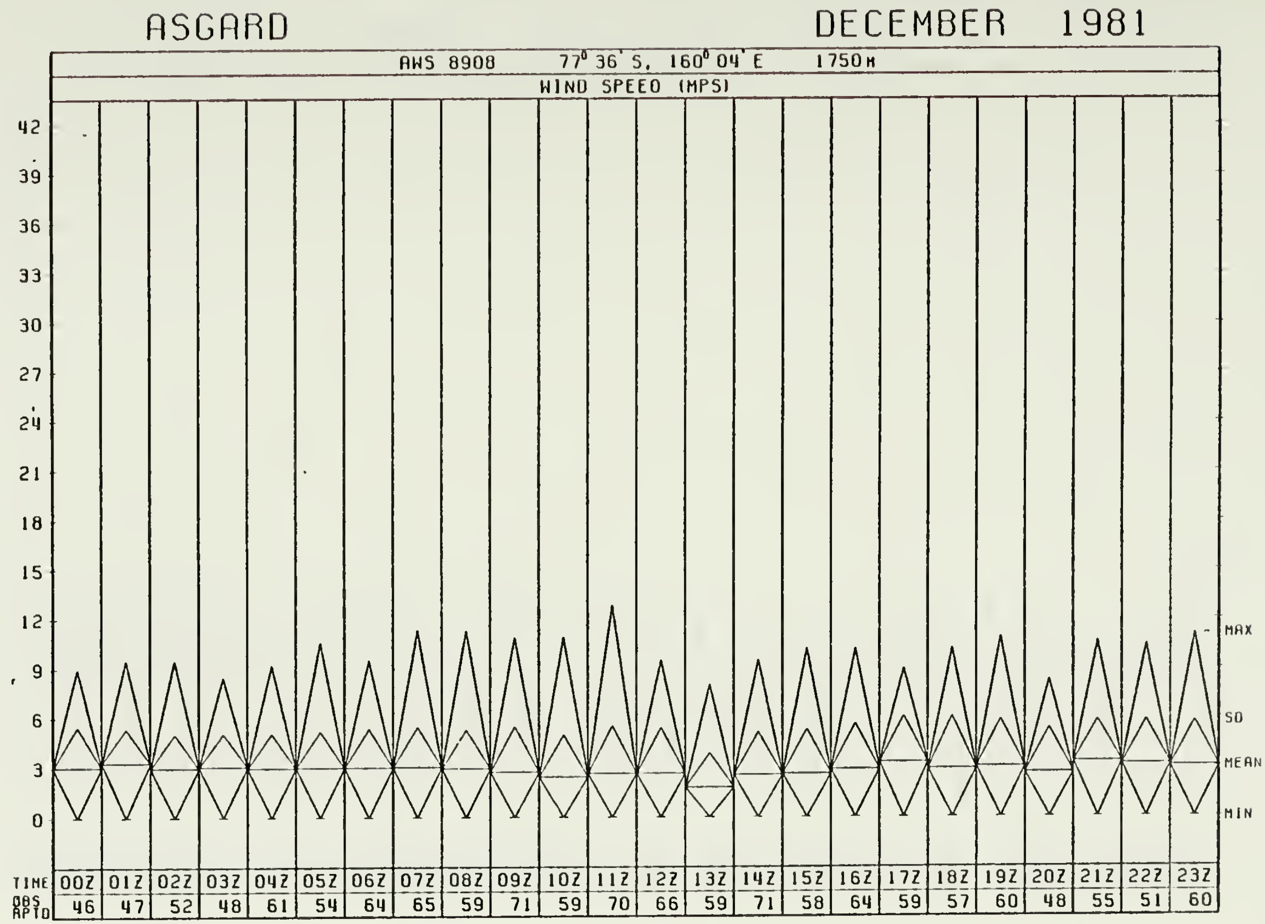


Figure 44. Diurnal Surface Wind Speed, Asgard, December 1981

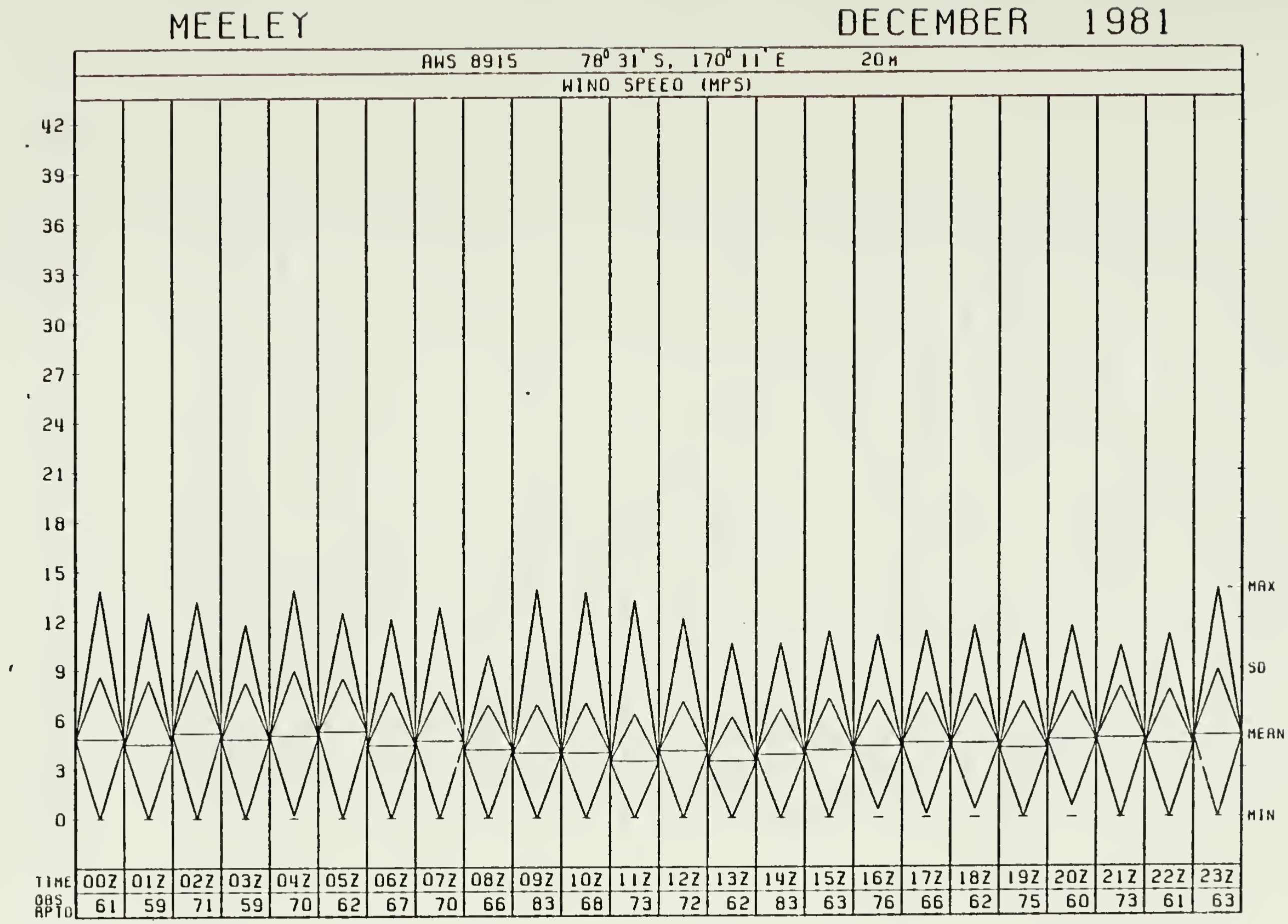


Figure 45. Diurnal Surface Wind Speed, Meeley, December 1981

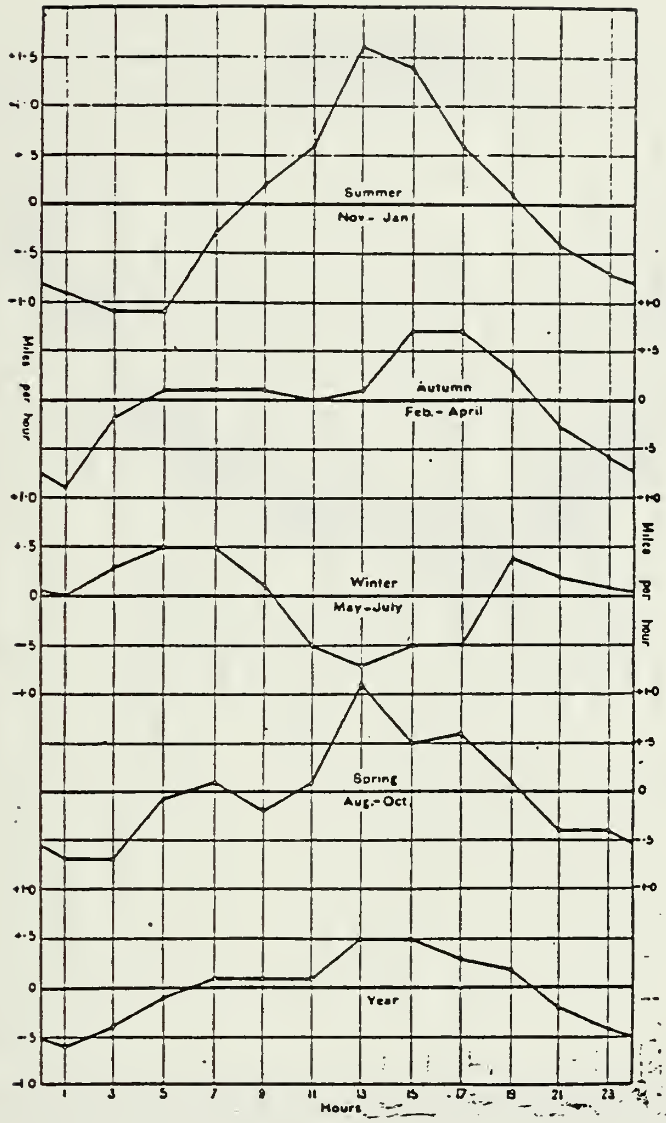


Figure 46. Diurnal Variation of Wind, McMurdo (Simpson, 1919)

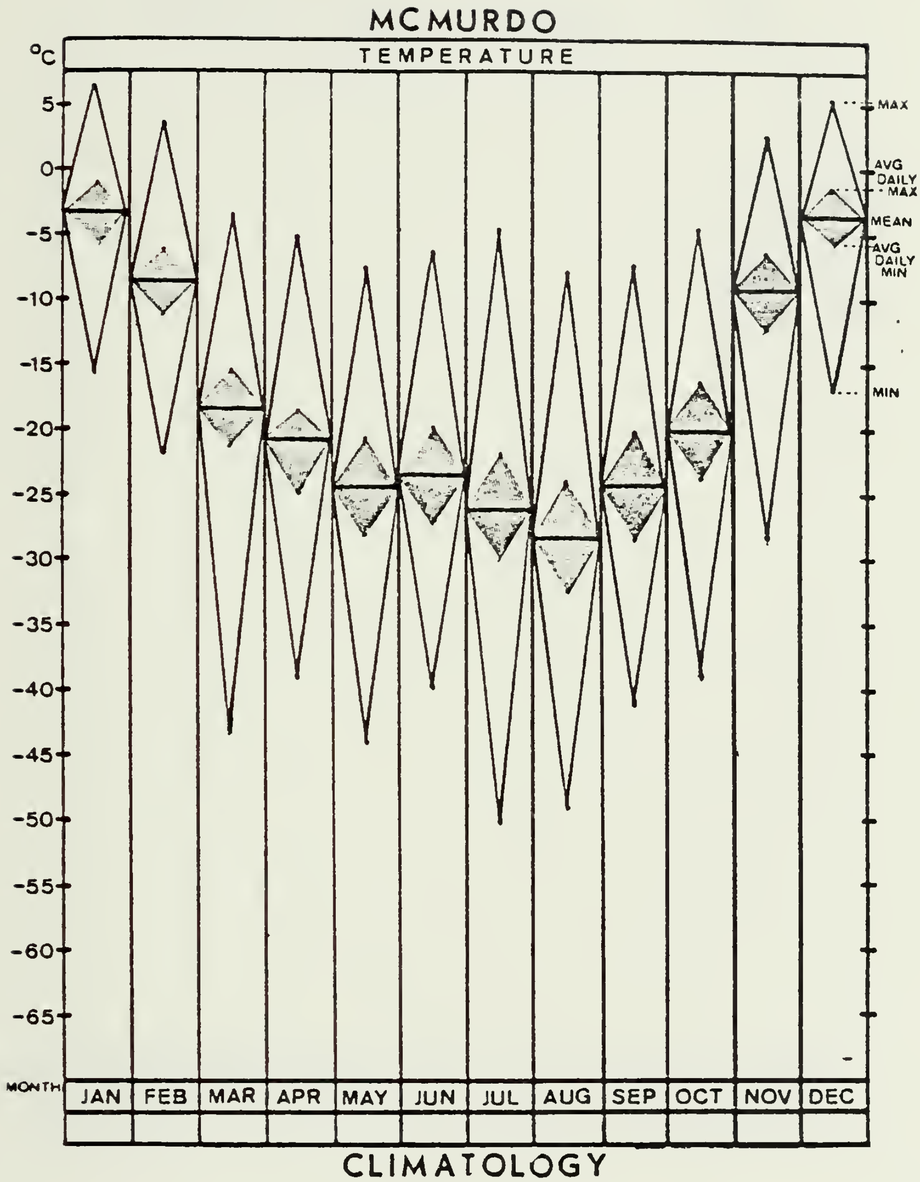


Figure 47. Monthly Surface Temperature Climatology, McMurdo (U.S. Naval Weather Service, 1970)

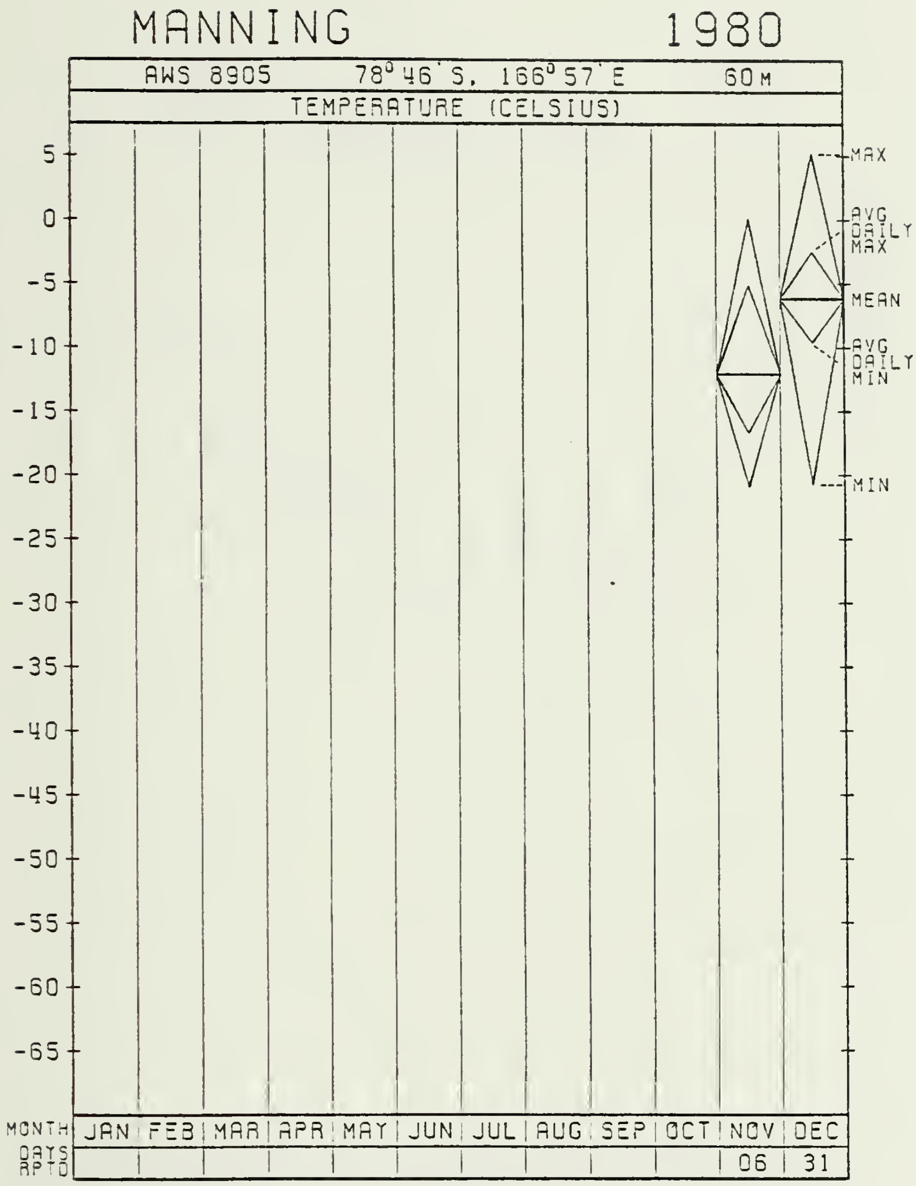


Figure 48. Monthly Surface Temperature, Manning, 1980

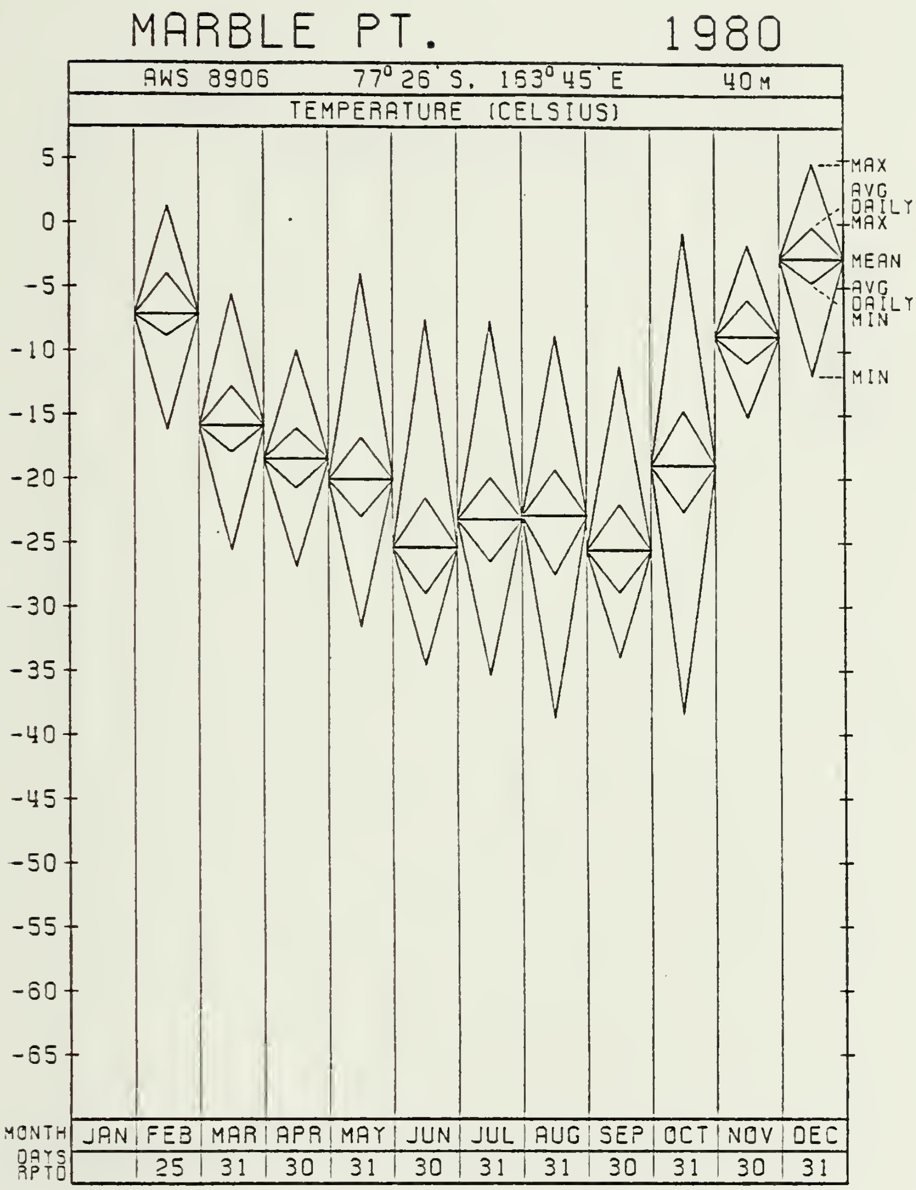


Figure 49. Monthly Surface Temperature, Marble Point, 1980

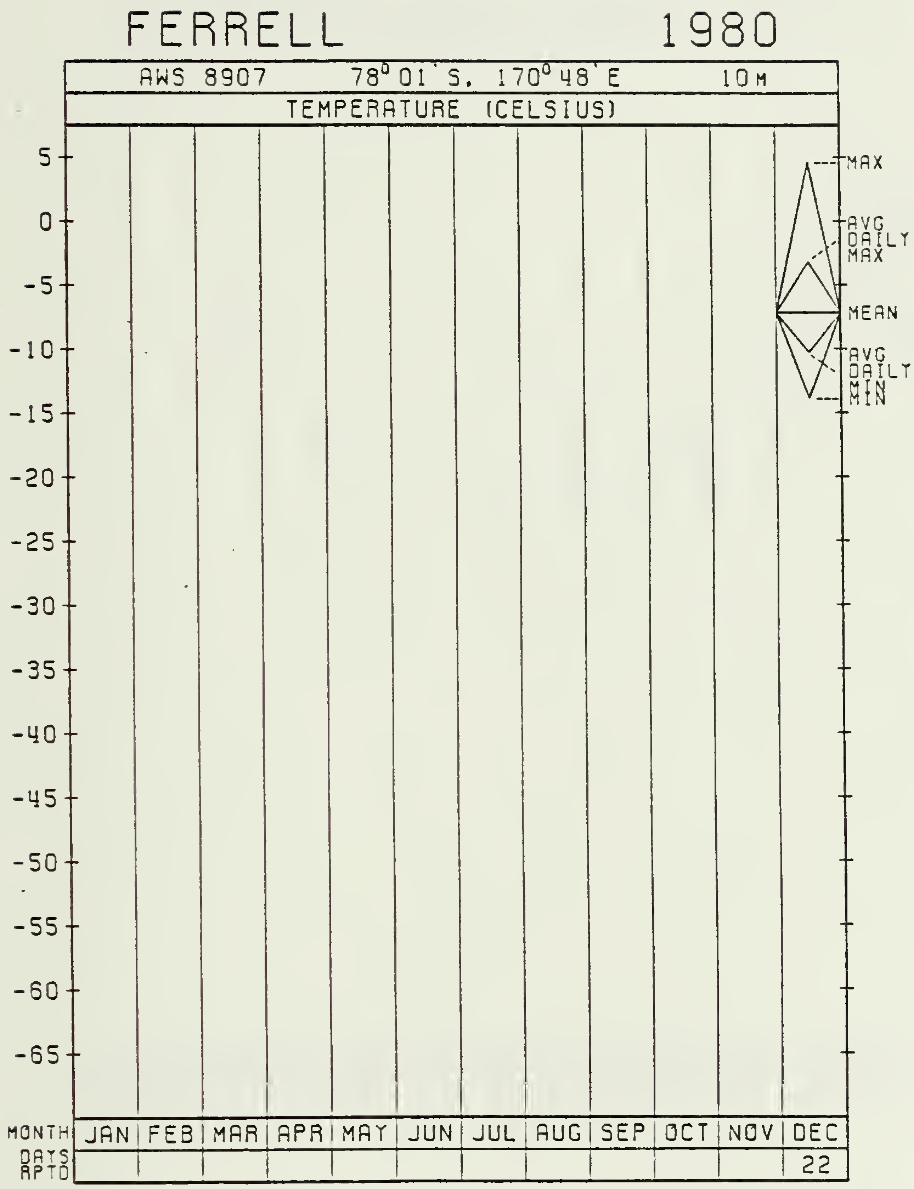


Figure 50. Monthly Surface Temperature, Ferrell, 1980

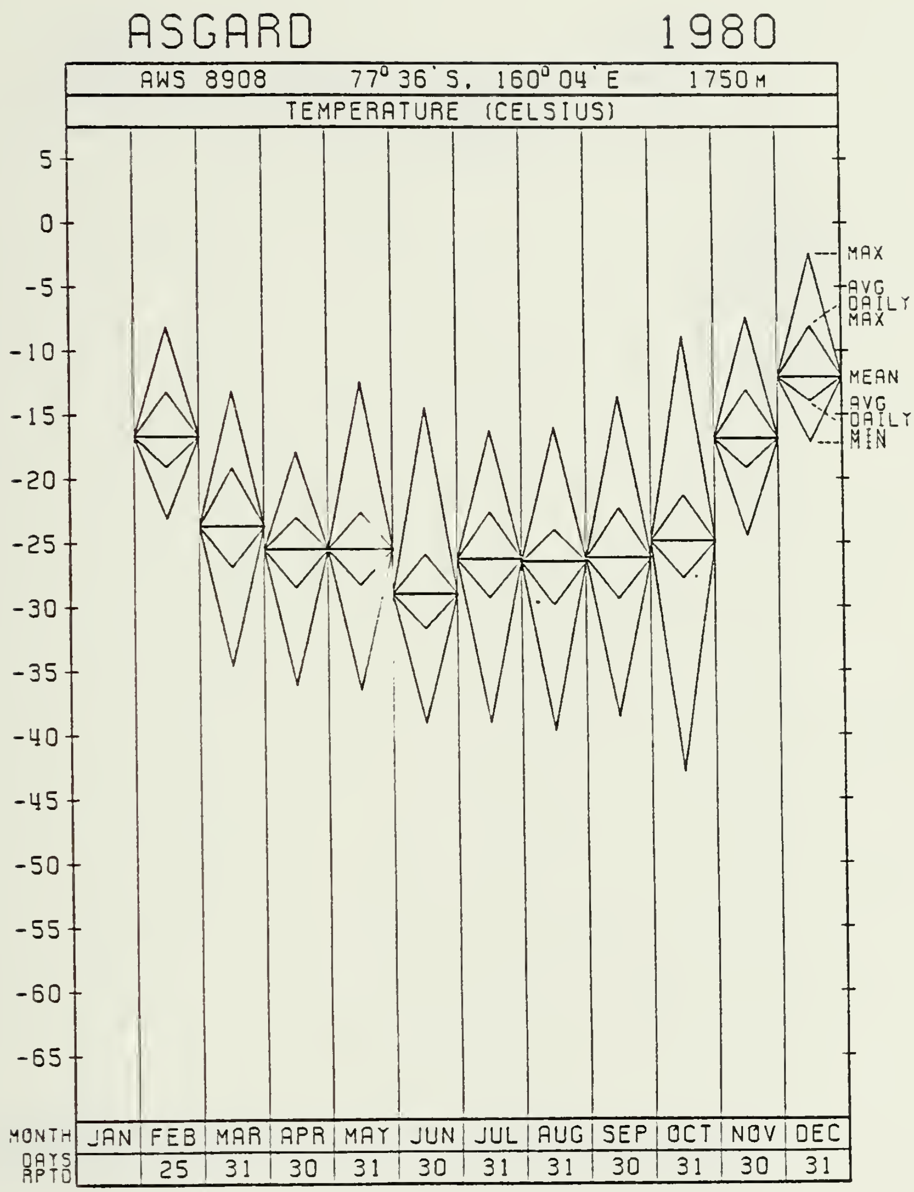


Figure 51. Monthly Surface Temperature, Asgard, 1980

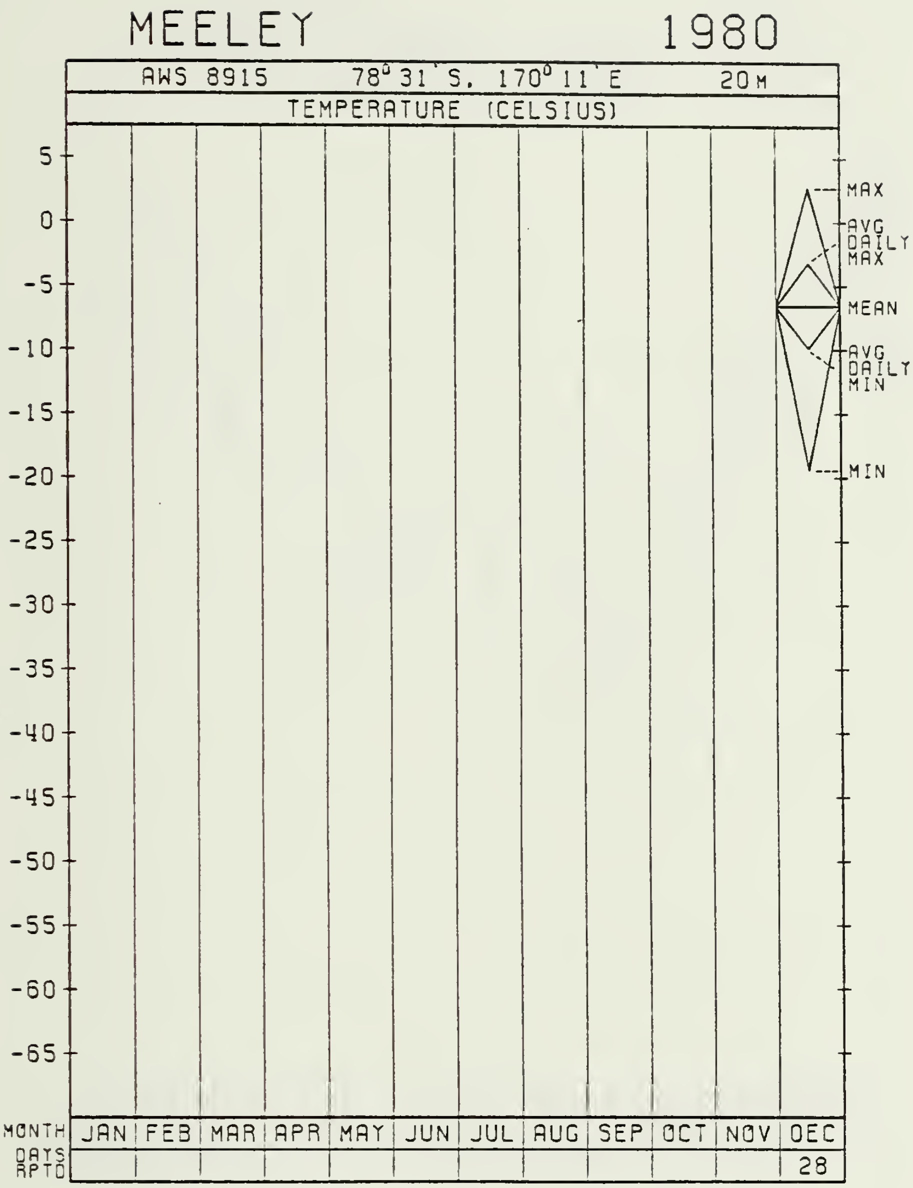


Figure 52. Monthly Surface Temperature, Meeley, 1980

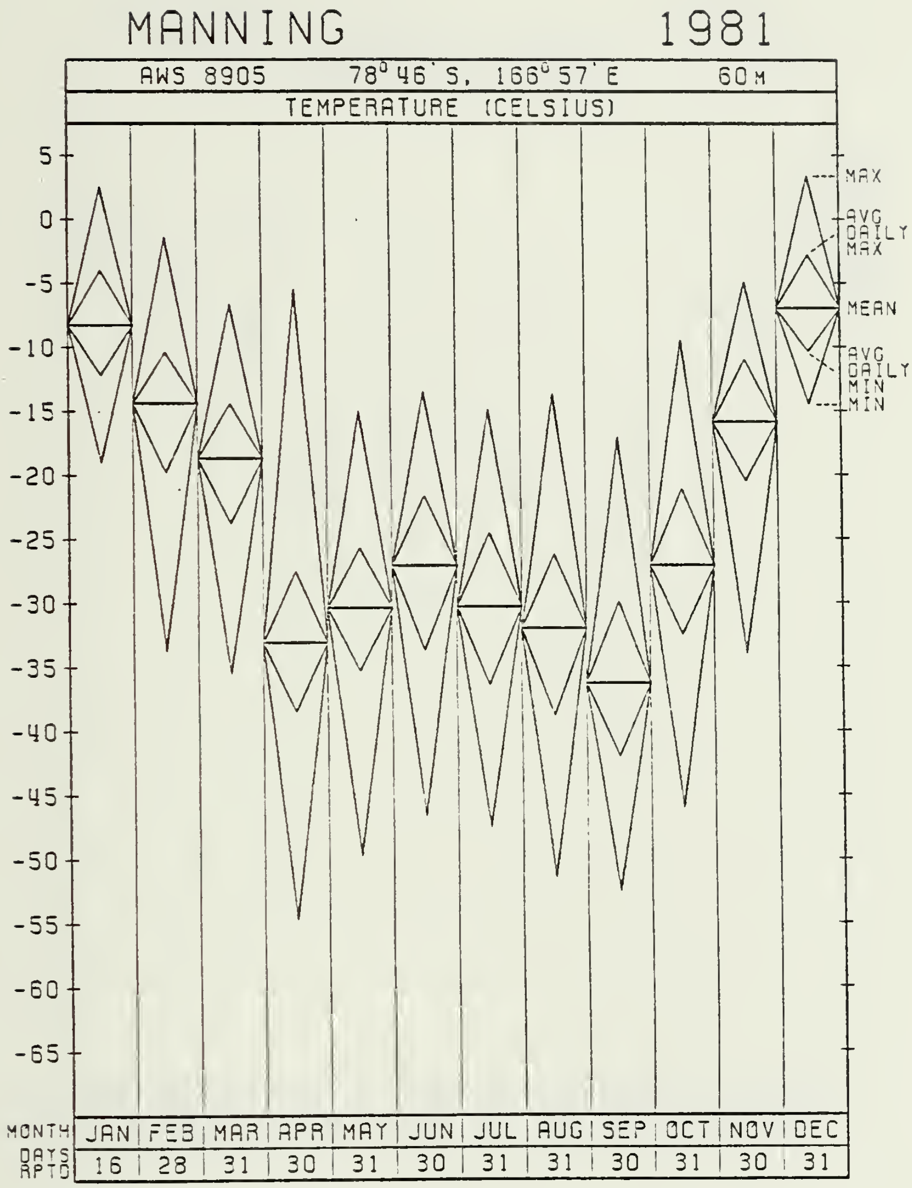


Figure 53. Monthly Surface Temperature, Manning, 1981

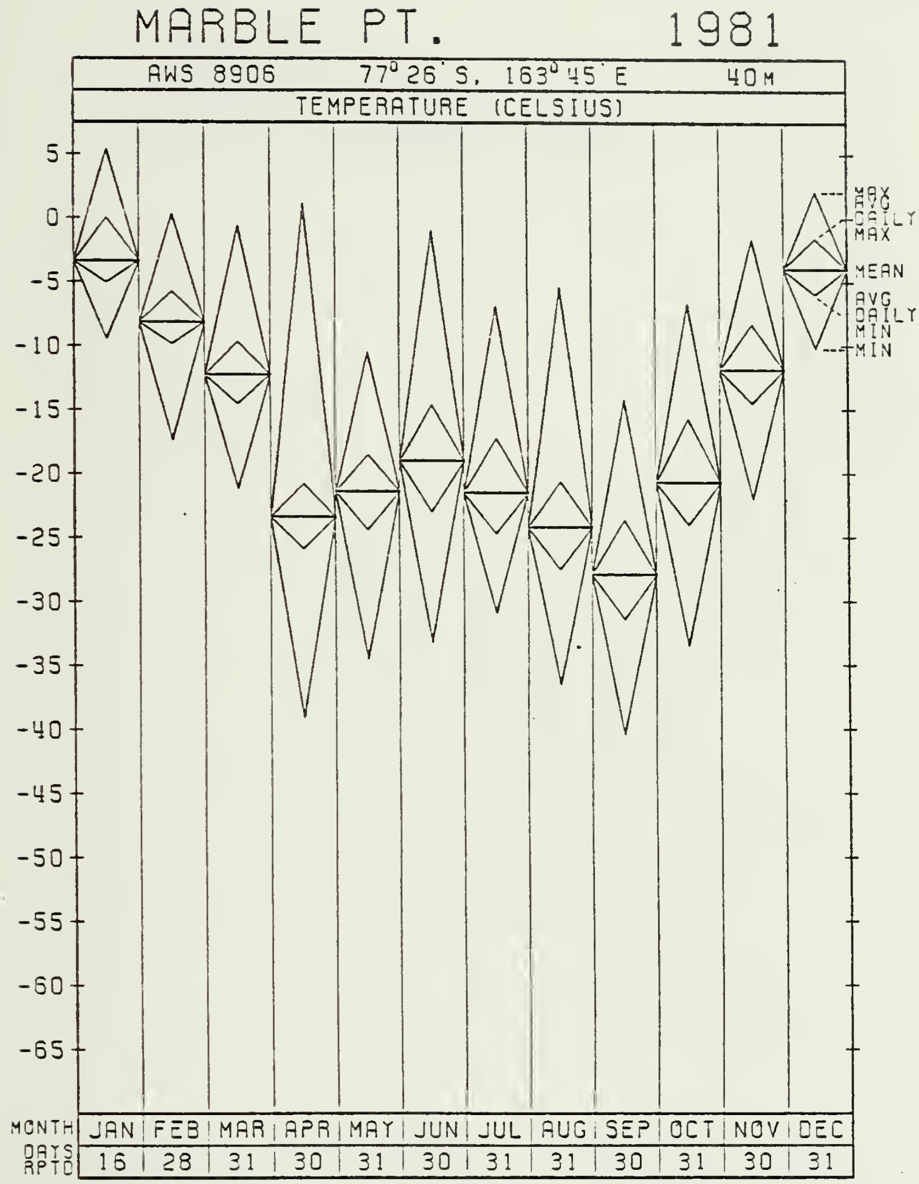


Figure 54. Monthly Surface Temperature, Marble Point, 1981

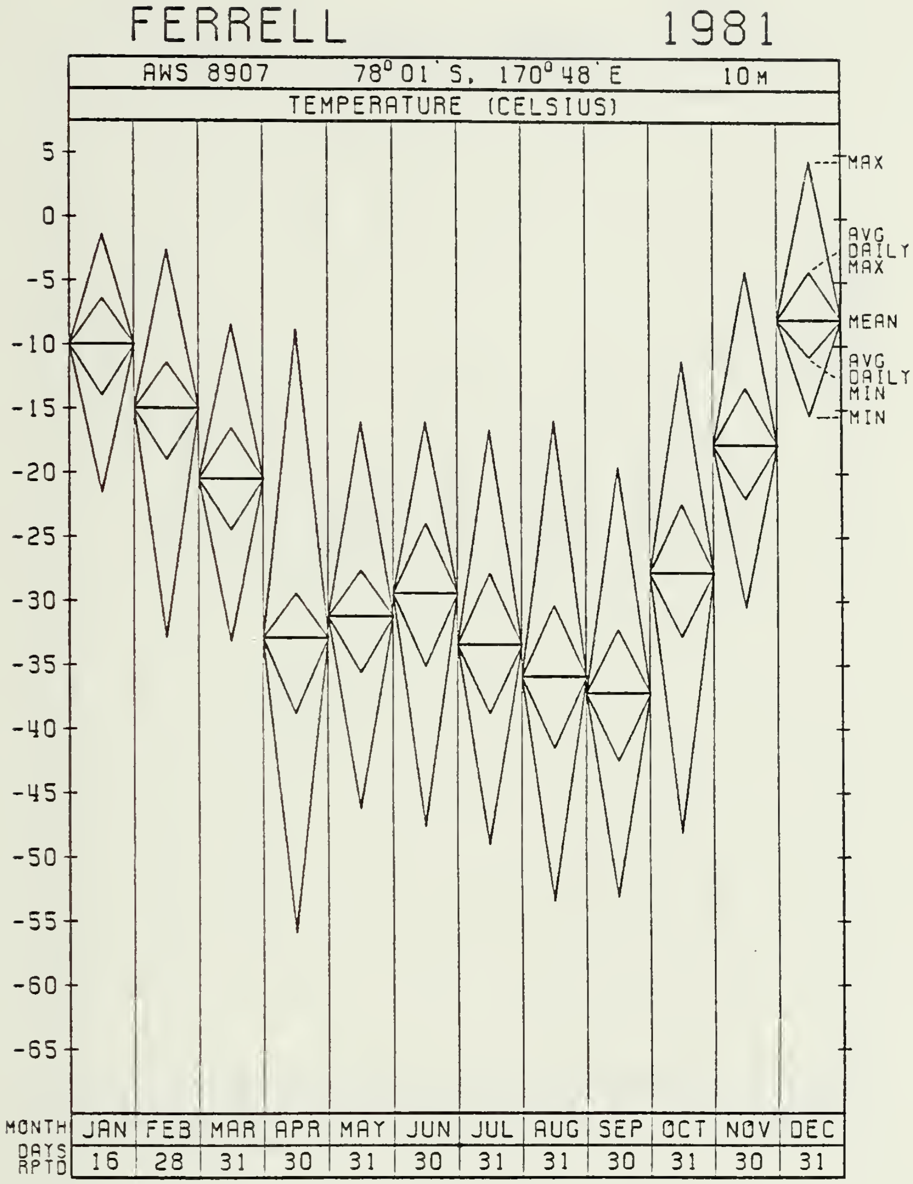


Figure 55. Monthly Surface Temperature, Ferrell, 1981

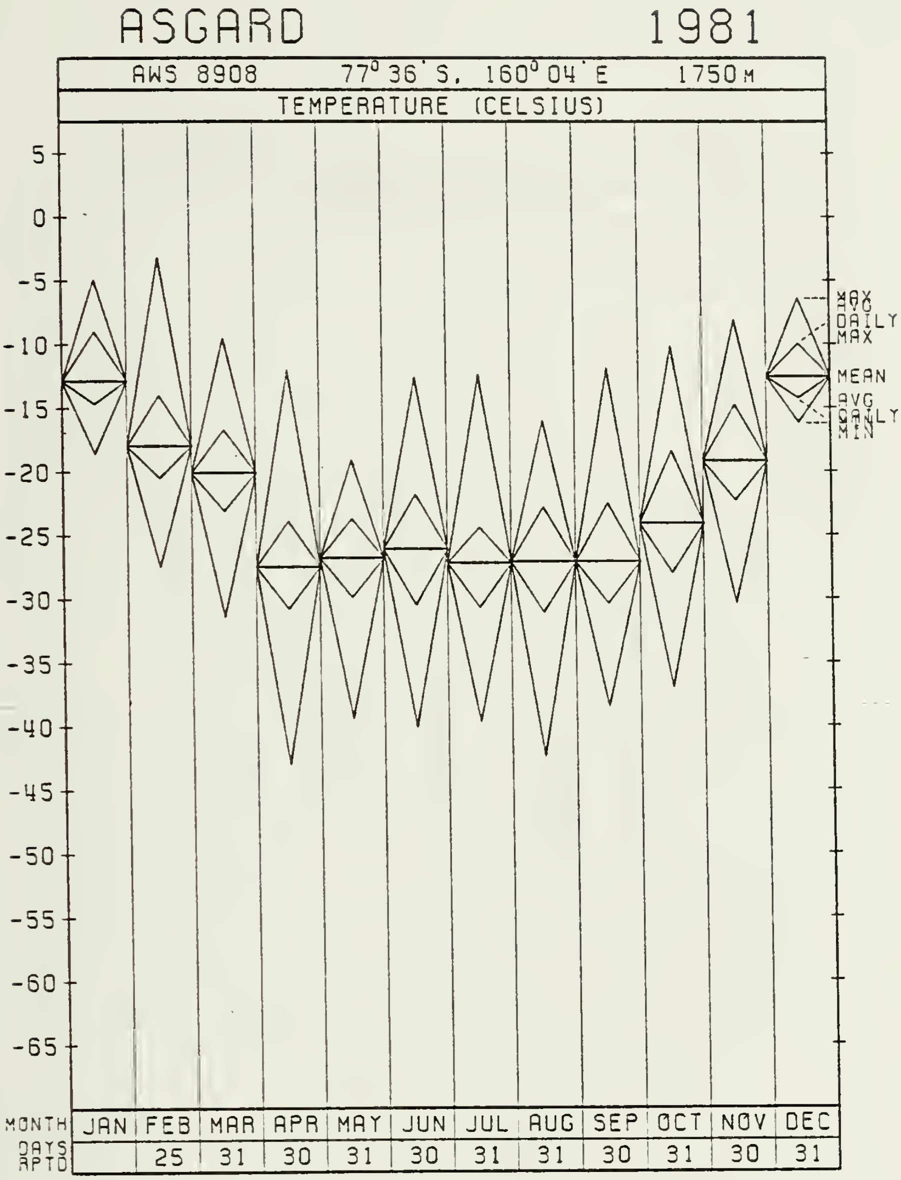


Figure 56. Monthly Surface Temperature, Asgard, 1981

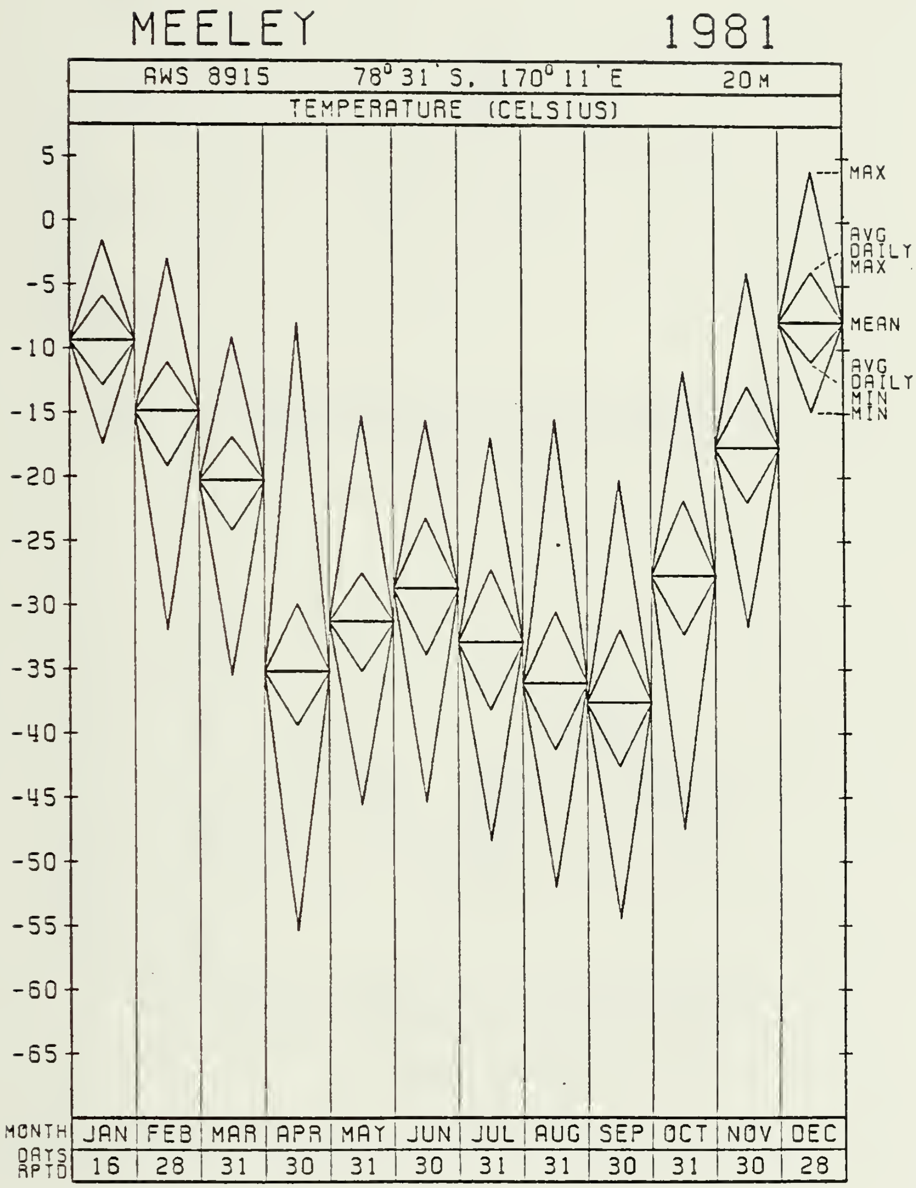
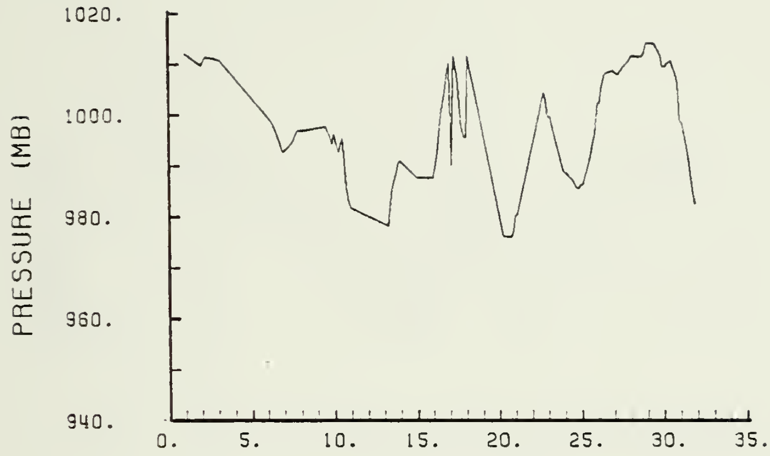
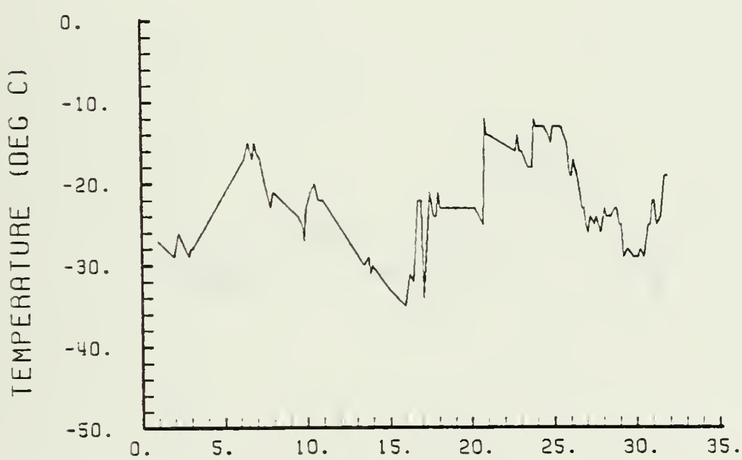


Figure 57. Monthly Surface Temperature, Meeley, 1981



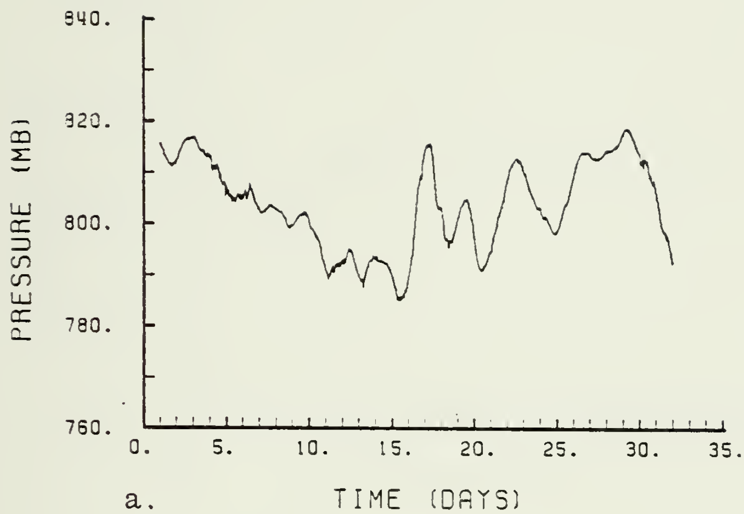
a.



b.

Figure 58a. Sea-level Pressure, McMurdo, July 1980
58b. Surface Temperature, McMurdo, July 1980 (observations at six-h intervals; some data missing. See Table VI).

Figure 59a. Surface Pressure, Marble Point, July 1980
59b. Surface Temperature, Marble Point, July 1980



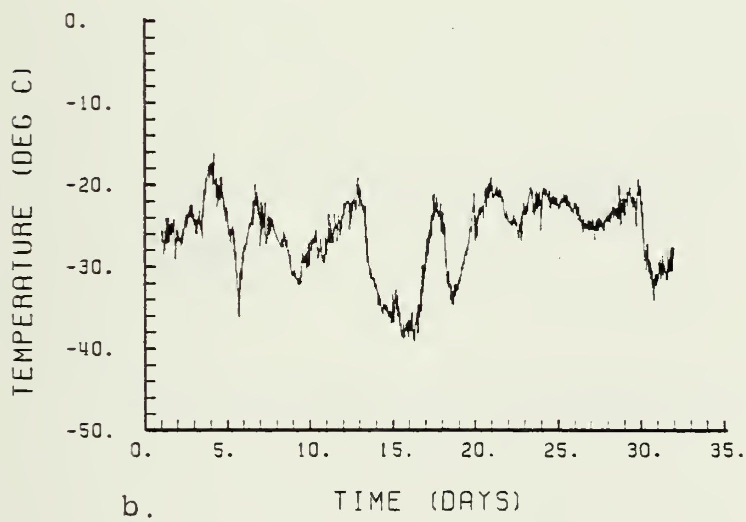
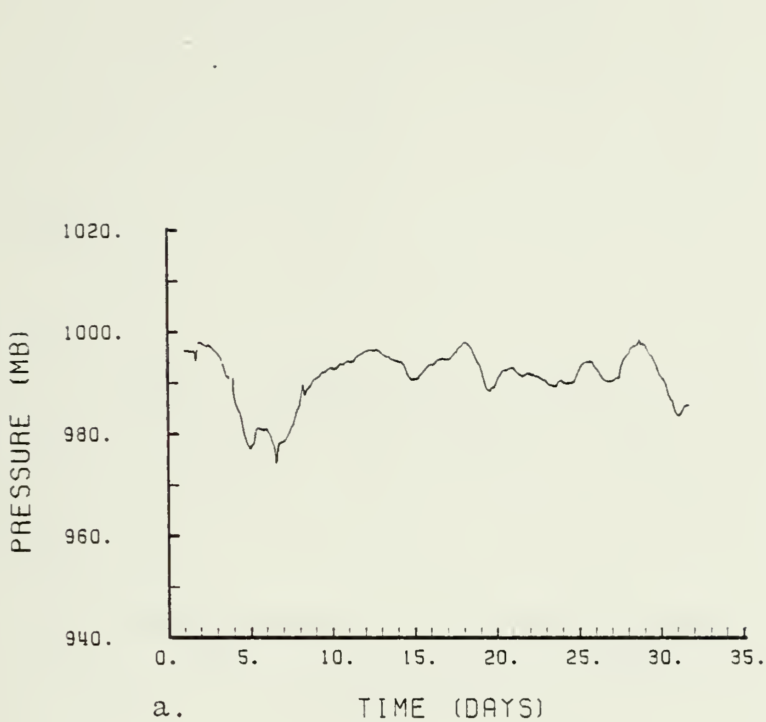


Figure 60a. Surface Pressure, Asgard, July 1980
60b. Surface Temperature, Asgard, July 1980



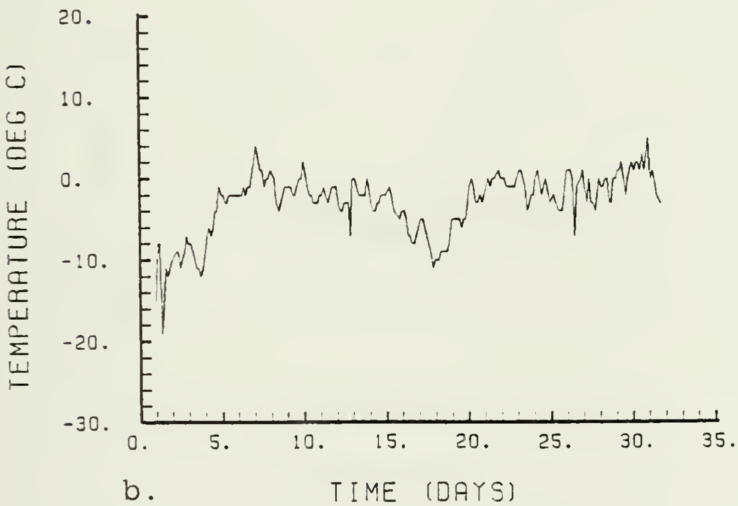


Figure 61a. Surface Pressure, McMurdo, December 1980
61b. Surface Temperature, McMurdo, December 1980 (observations at three-h intervals; some data missing. See Table IV).

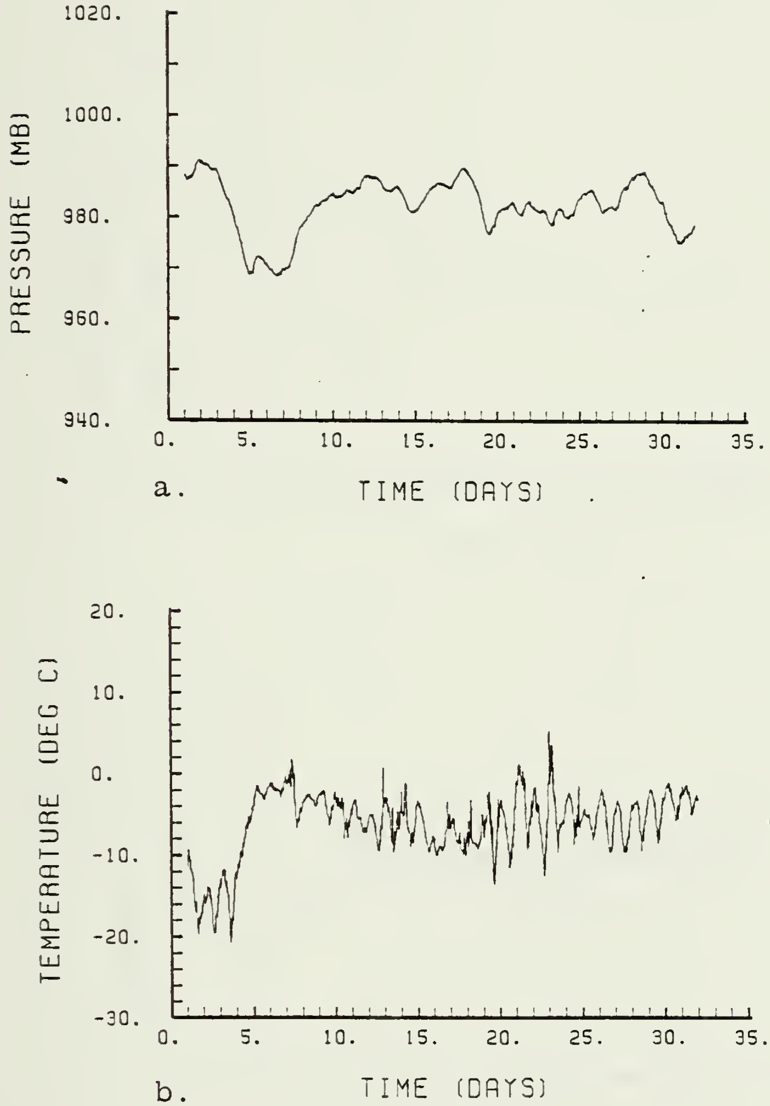


Figure 62a. Surface Pressure, Manning, December 1980
62b. Surface Temperature, Manning, December 1980

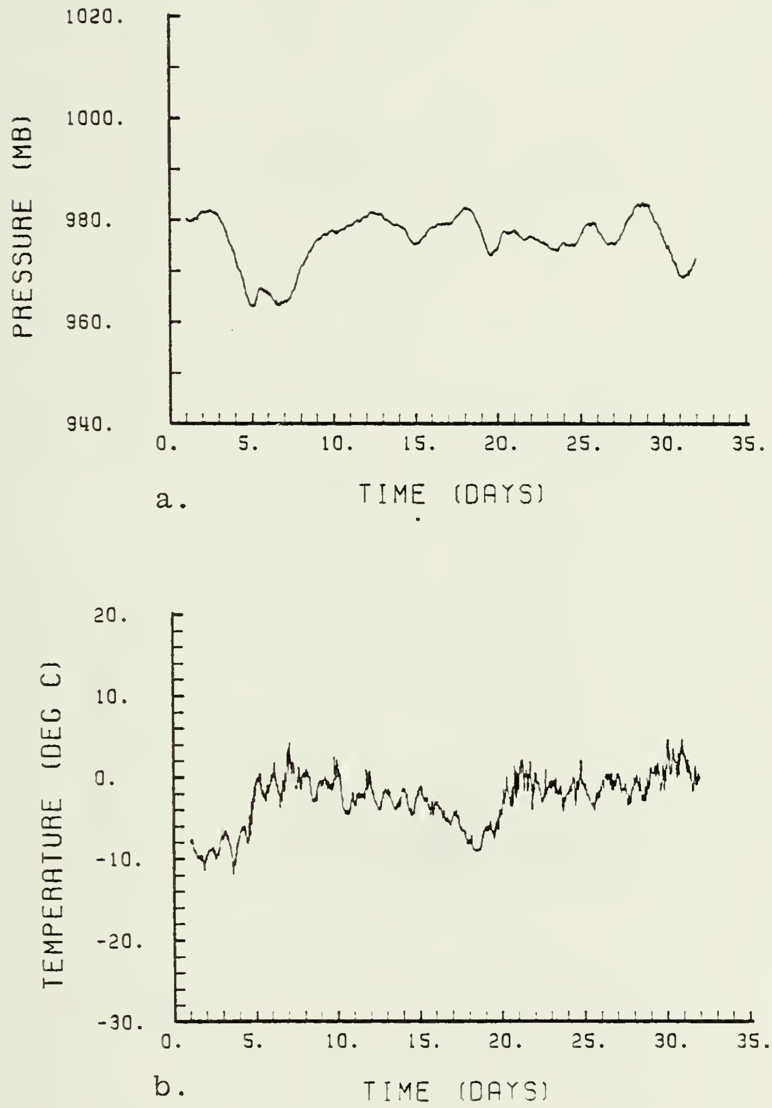


Figure 63a. Surface Pressure, Marble Point, December 1980
63b. Surface Temperature, Marble Point, December 1980

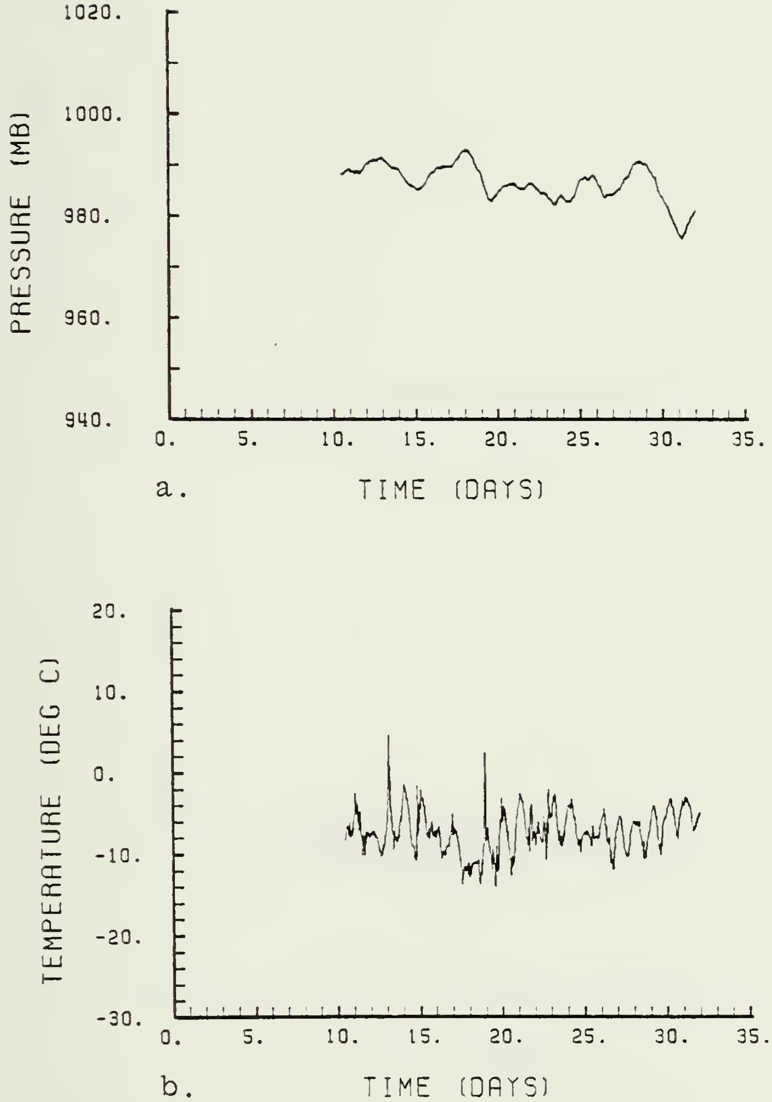
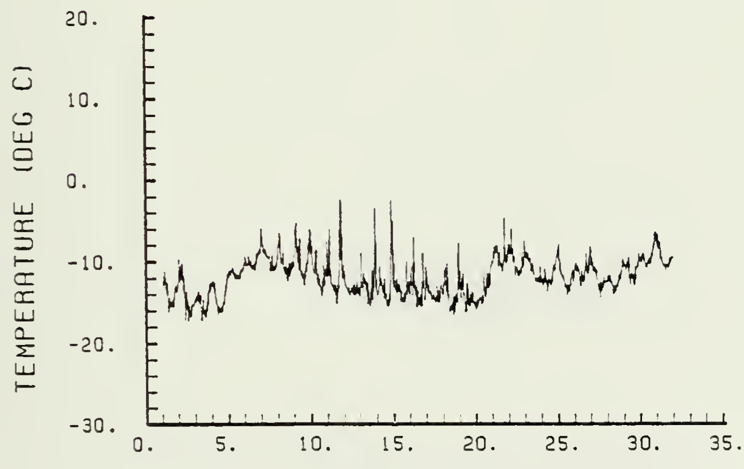


Figure 64a. Surface Pressure, Ferrell, December 1980
64b. Surface Temperature, Ferrell, December 1980

a.



b.

Figure 65a. Surface Pressure, Asgard, December 1980
65b. Surface Temperature, Asgard, December 1980

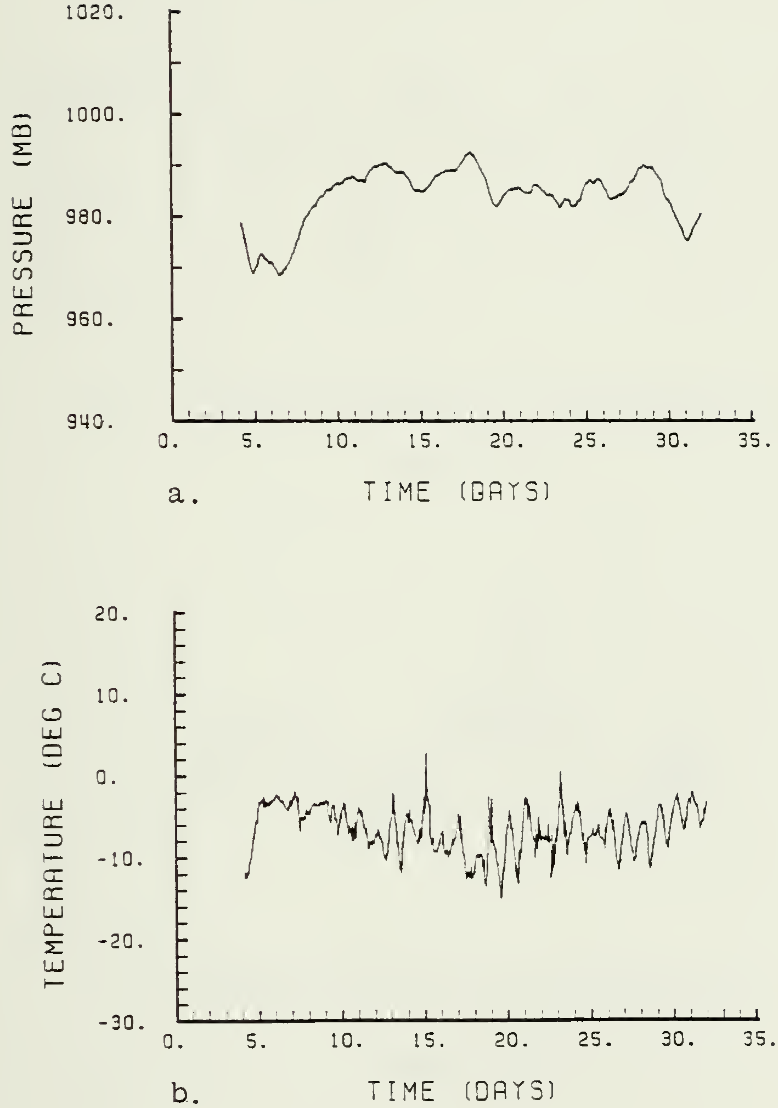
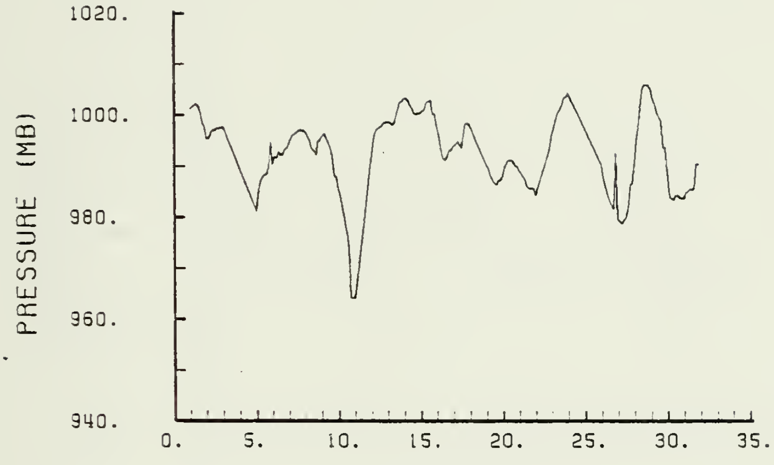
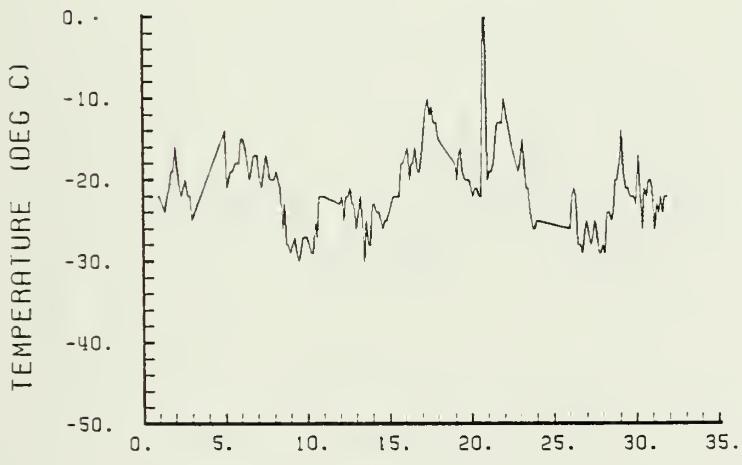


Figure 66a. Surface Pressure, Meeley, December 1980
66b. Surface Temperature, Meeley, December 1980

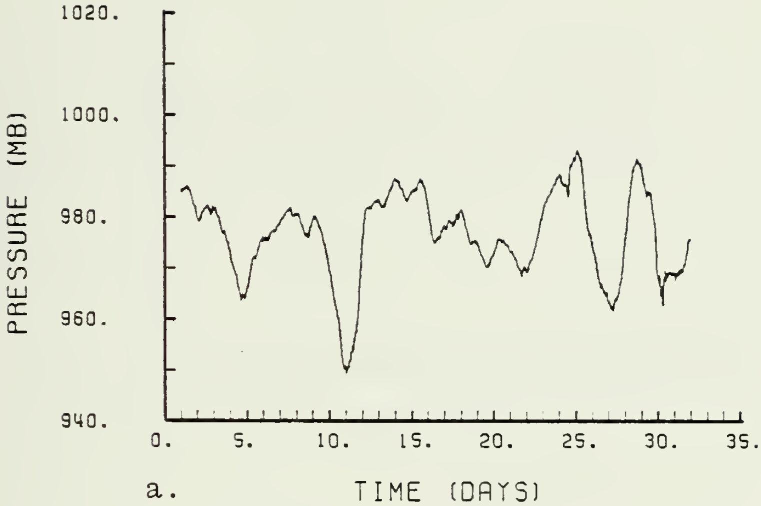


a.



b.

Figure 67a. Surface Pressure, McMurdo, July 1981
67b. Surface Temperature, McMurdo, July 1981 (observations at three-h intervals; some data missing. See Table IV).



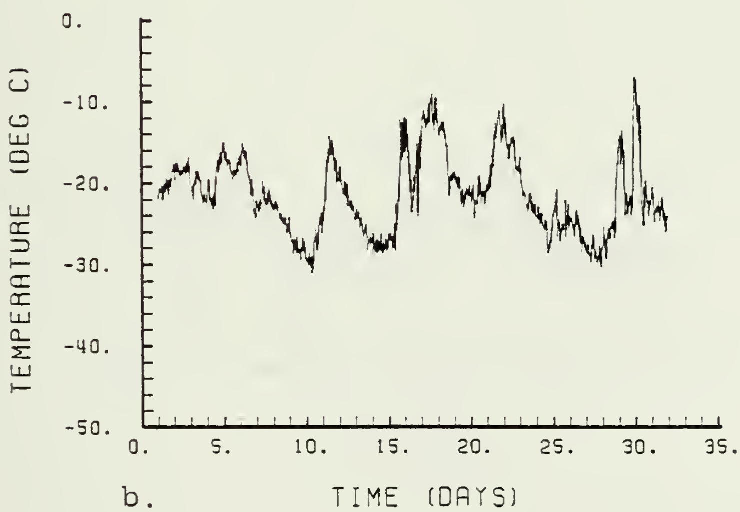


Figure 68a. Surface Pressure, Marble Point, July 1981
68b. Surface Temperature, Marble Point, July 1981

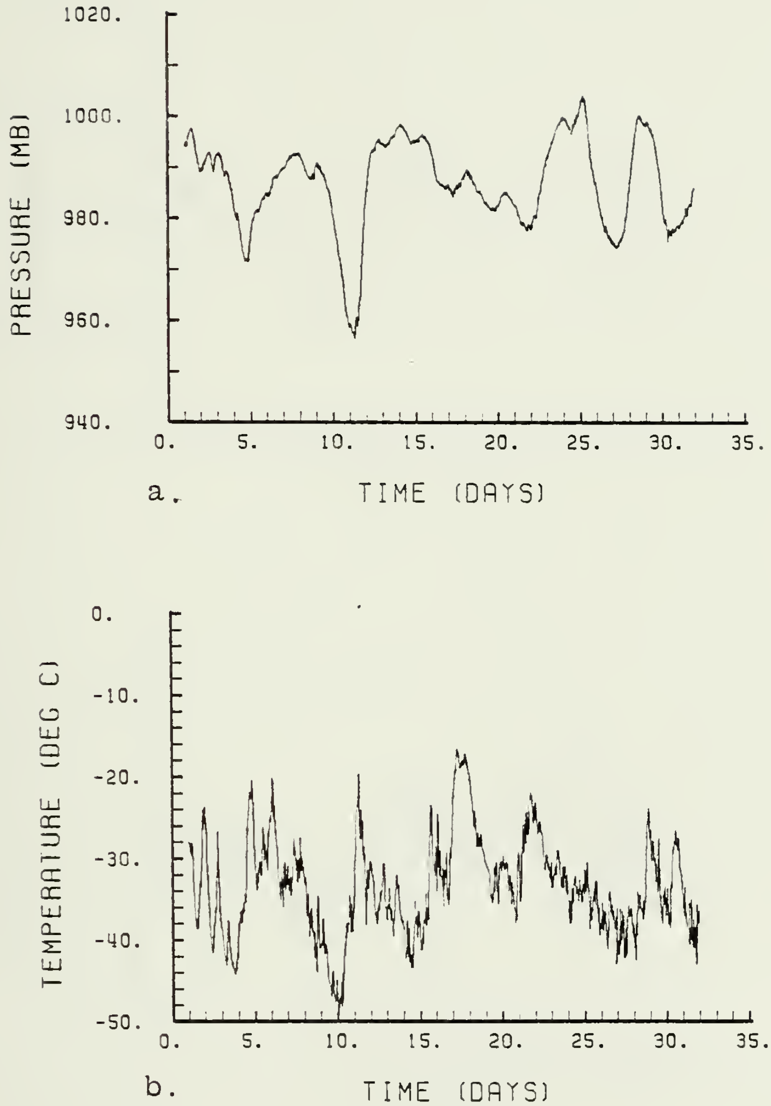
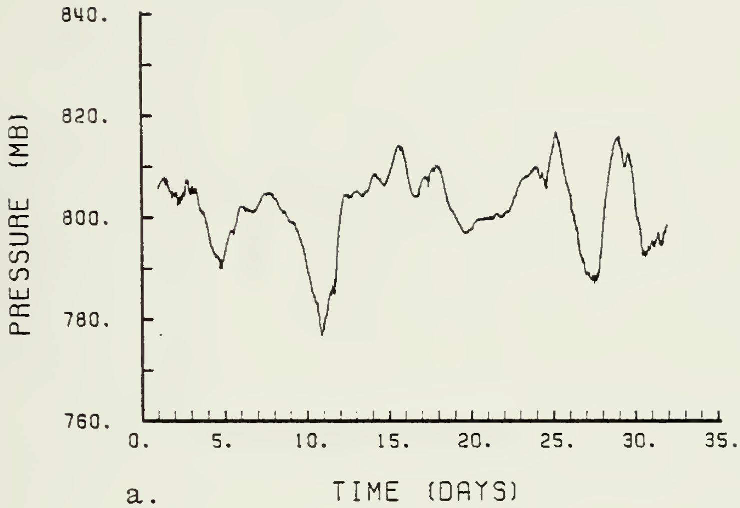
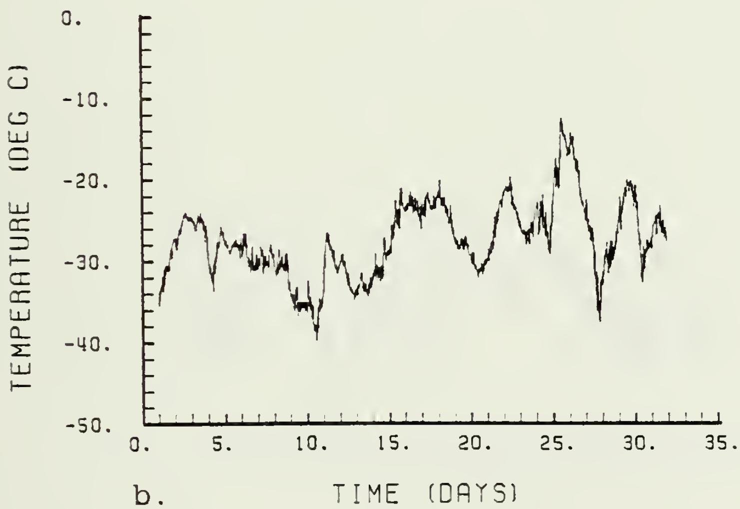


Figure 69a. Surface Pressure, Ferrell, July 1981
69b. Surface Temperature, Ferrell, July 1981



a.



b.

Figure 70a. Surface Pressure, Asgard, July 1981
70b. Surface Temperature, Asgard, July 1981

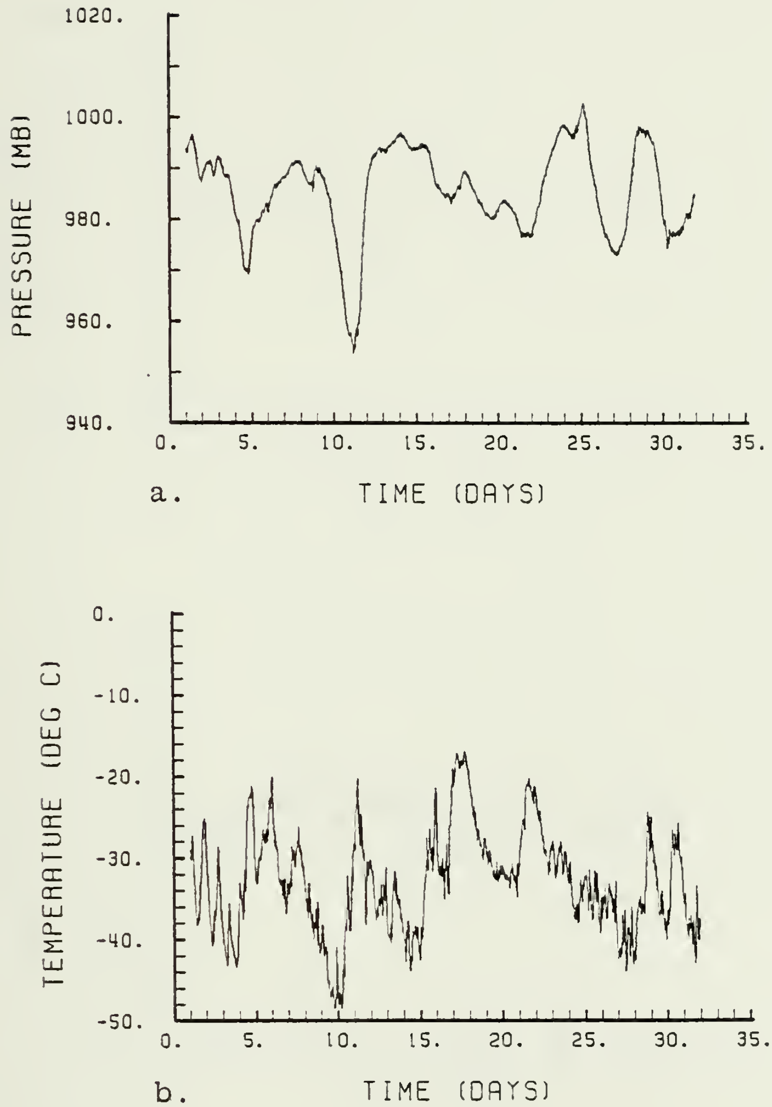


Figure 71a. Surface Pressure, Meeley, July 1981
71b. Surface Temperature, Meeley, July 1981

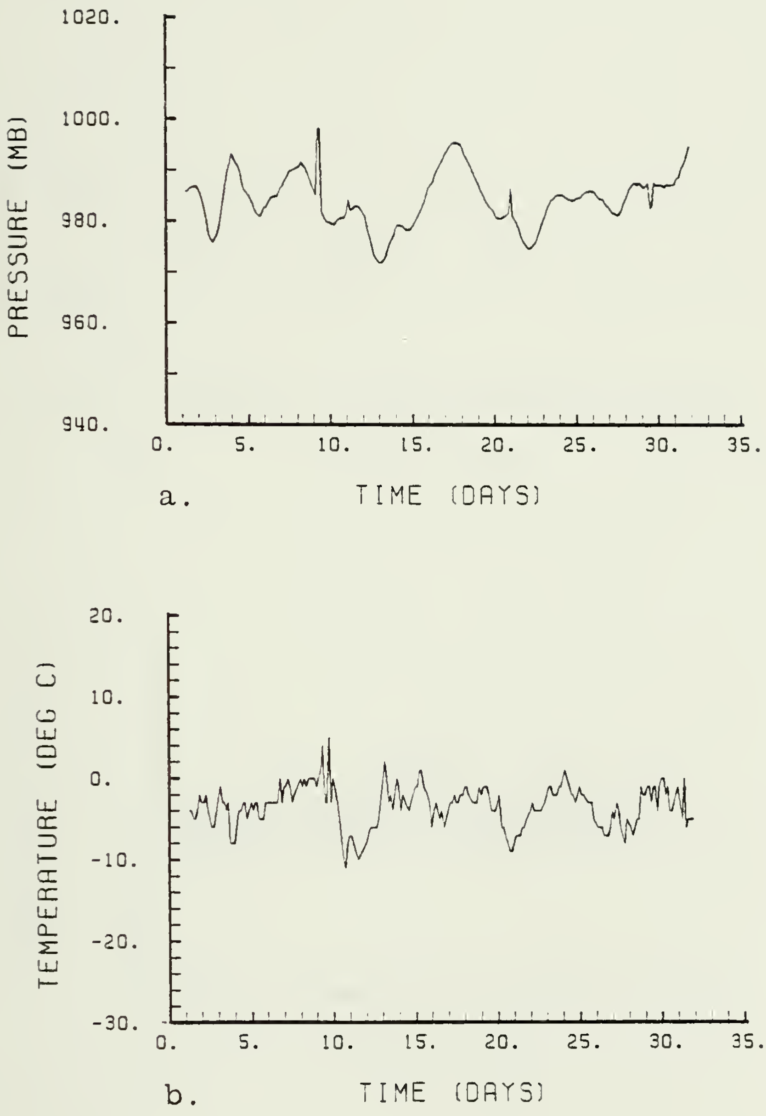


Figure 72a. Surface Pressure, McMurdo, December 1981
72b. Surface Temperature, McMurdo, December 1981 (observations at three-h intervals; some data missing. See Table VI).

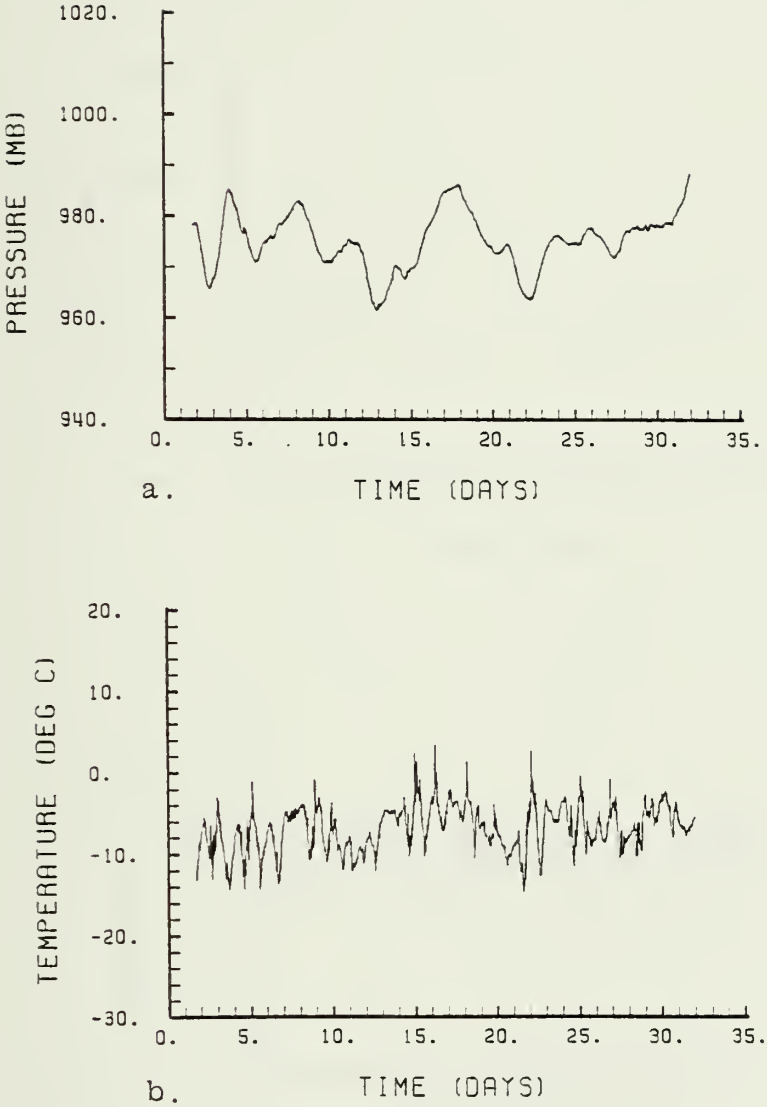
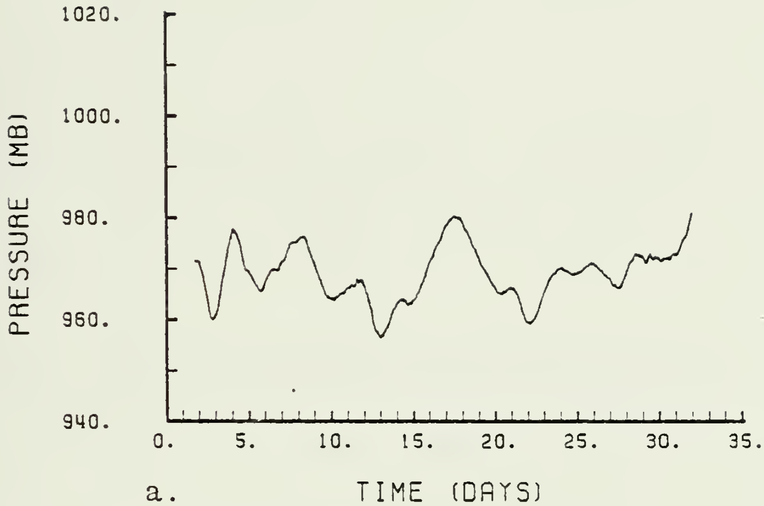


Figure 73a. Surface Pressure, Manning, December 1981
73b. Surface Temperature, Manning, December 1981



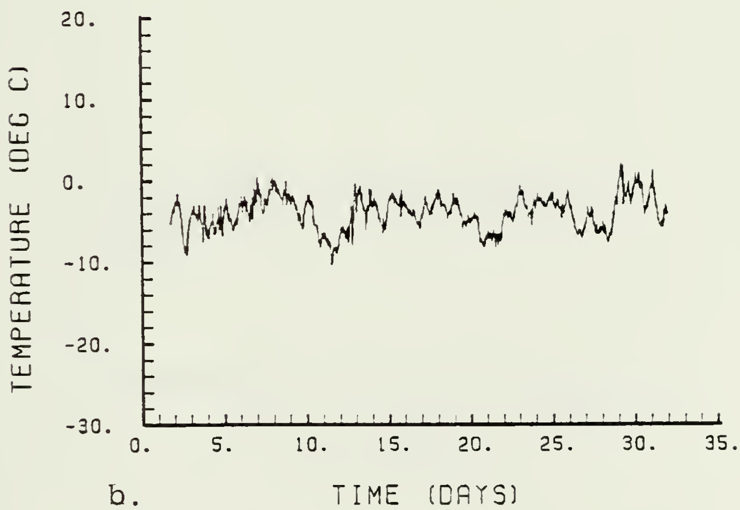


Figure 74a. Surface Pressure, Marble Point, December 1981
74b. Surface Temperature, Marble Point, December 1981.

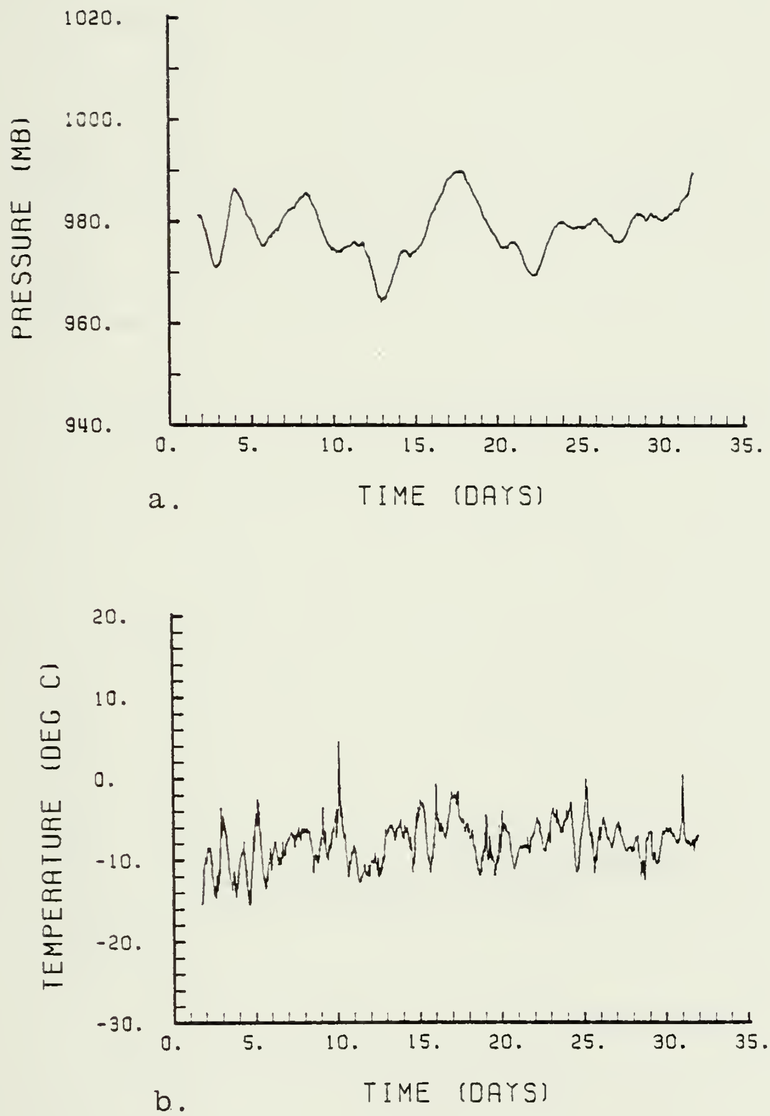


Figure 75a. Surface Pressure, Ferrell, December 1981
75b. Surface Temperature, Ferrell, December 1981

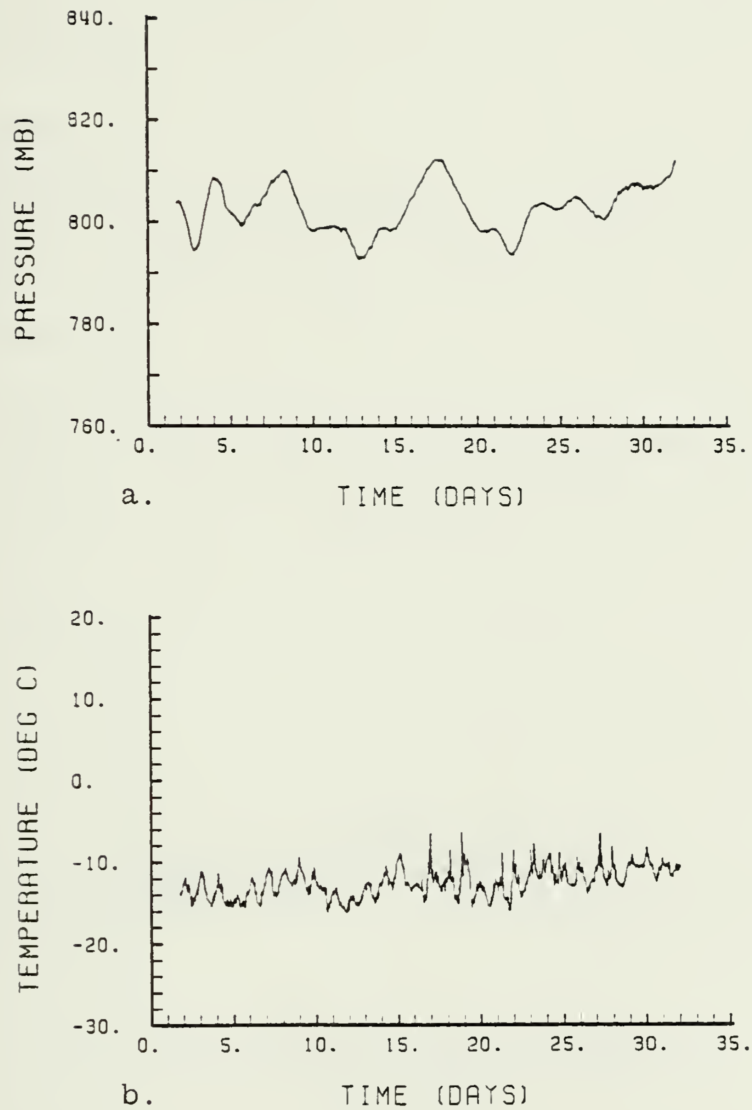


Figure 76a. Surface Pressure, Asgard, December 1981
76b. Surface Temperature, Asgard, December 1981

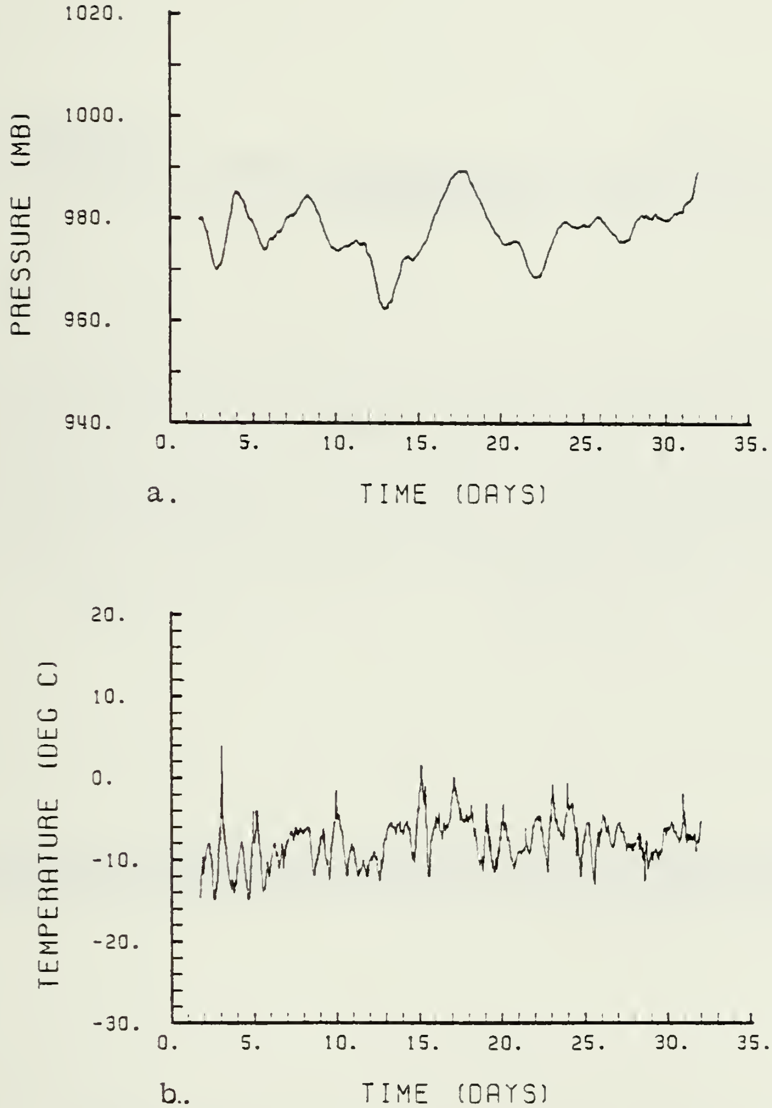


Figure 77a. Surface Pressure, Meeley, December 1981
77b. Surface Temperature, Meeley, December 1981

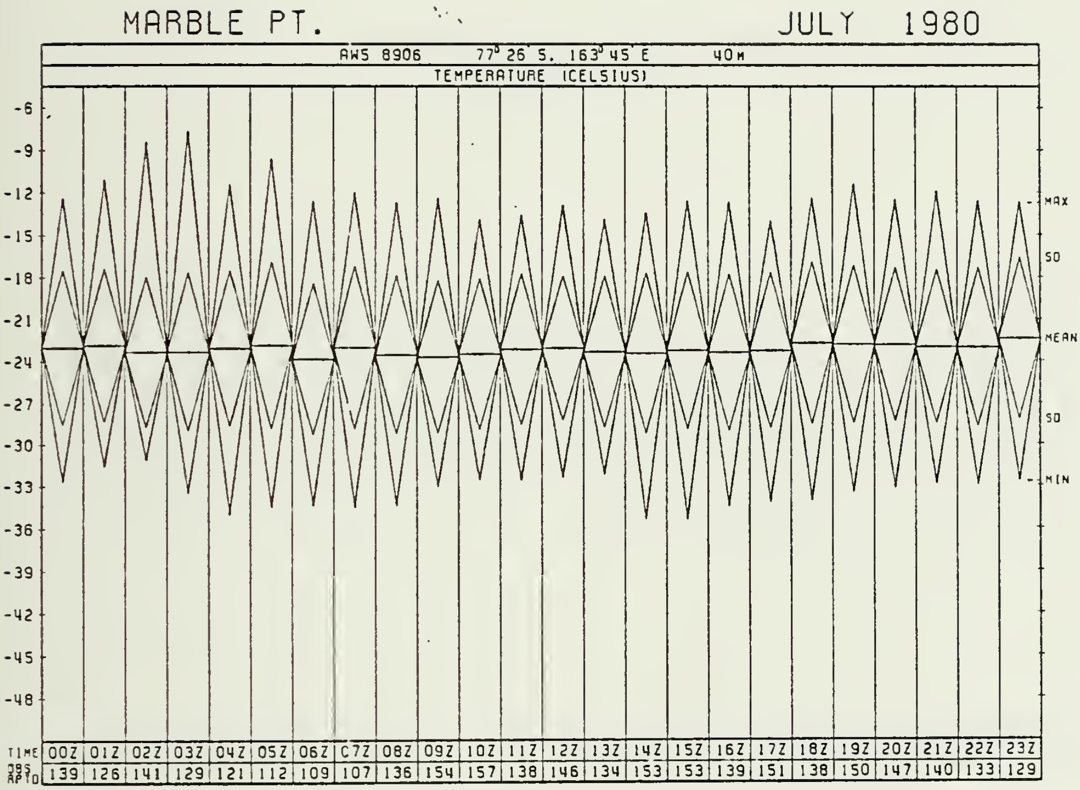


Figure 78. Diurnal Surface Temperature, Marble Point, July 1980

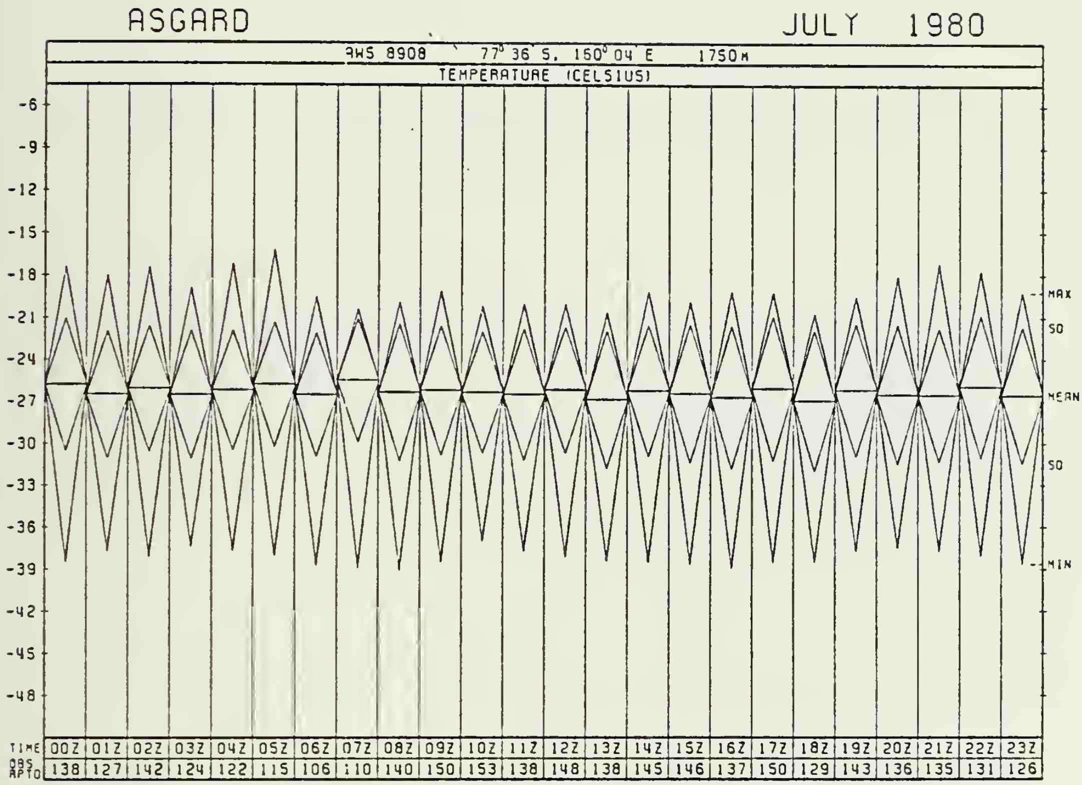


Figure 79. Diurnal Surface Temperature, Asgard, July 1980

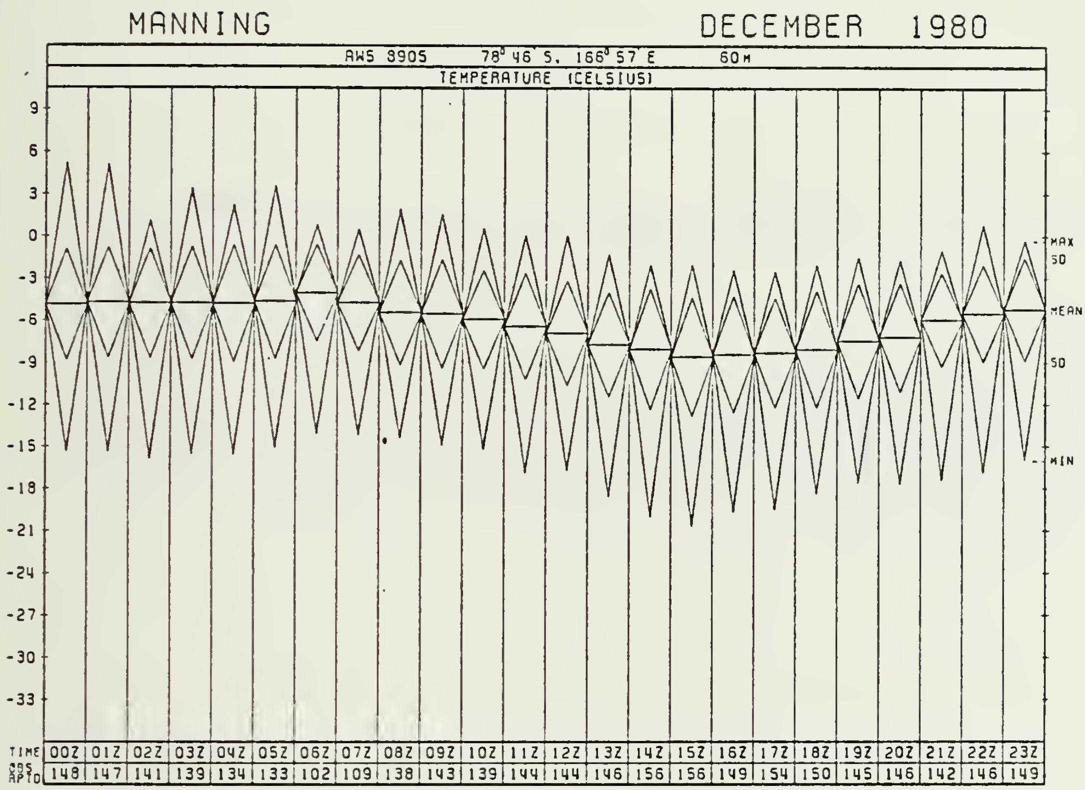


Figure 80. Diurnal Surface Temperature, Manning, December 1980

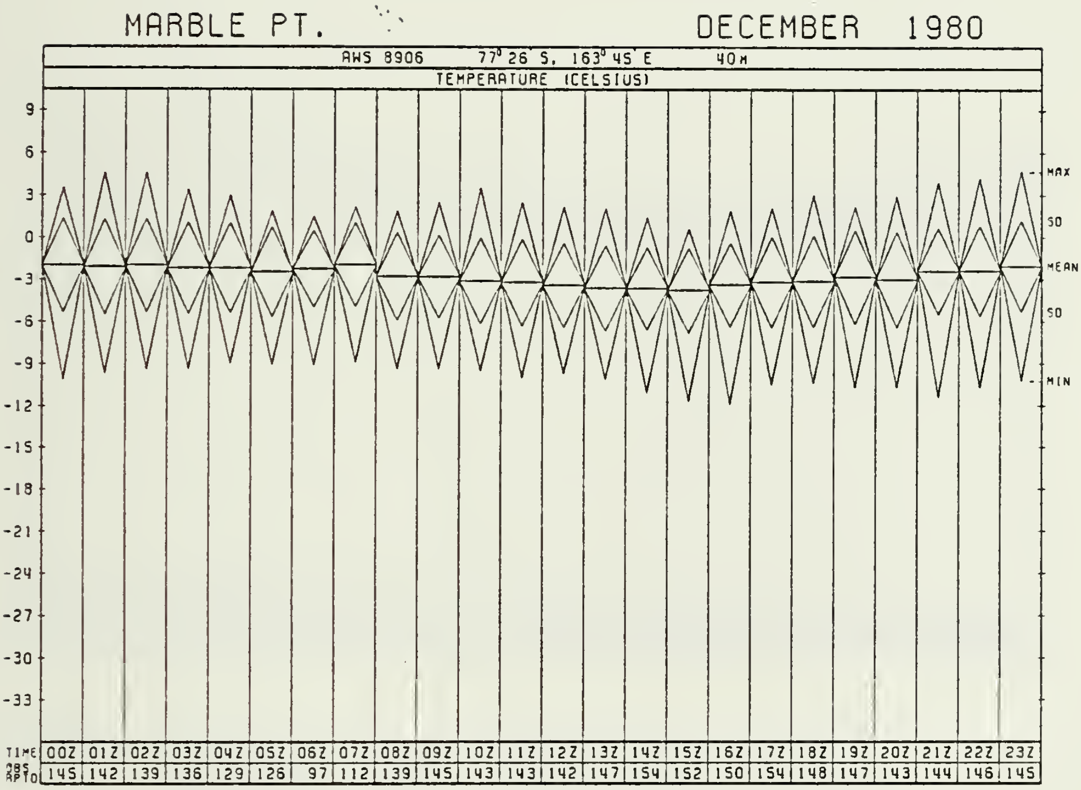


Figure 81. Diurnal Surface Temperature, Marble Point, December 1980

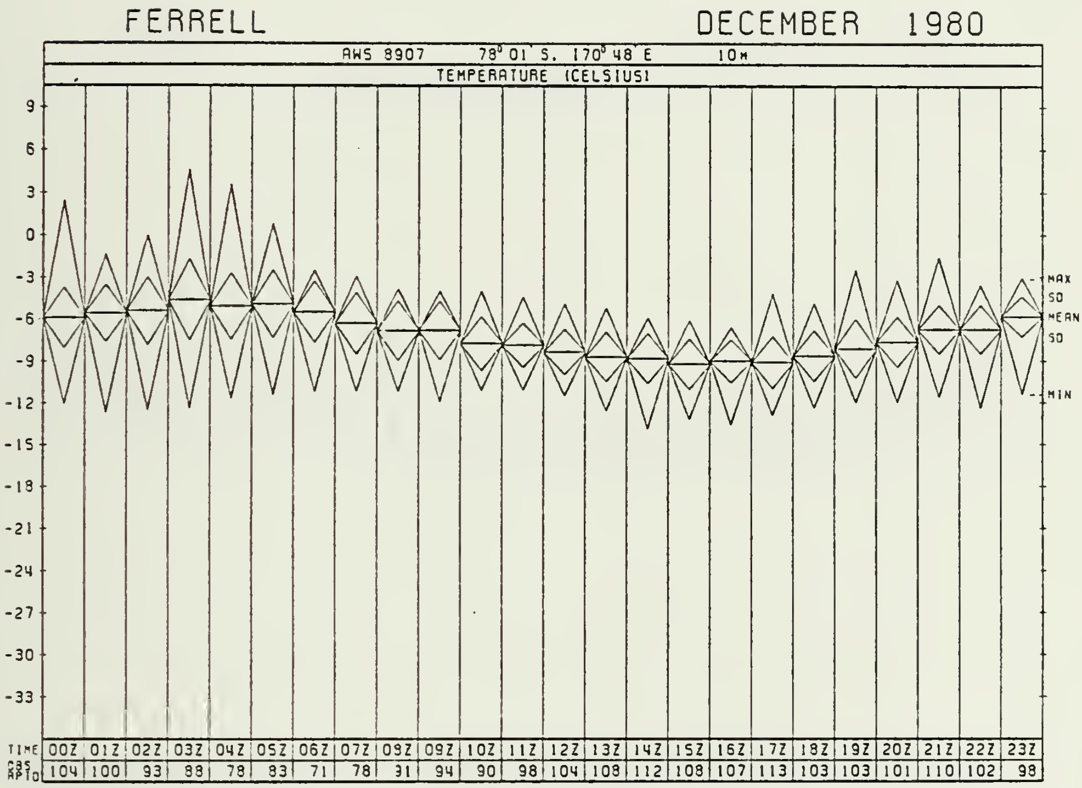


Figure 82. Diurnal Surface Temperature, Ferrell, December 1980

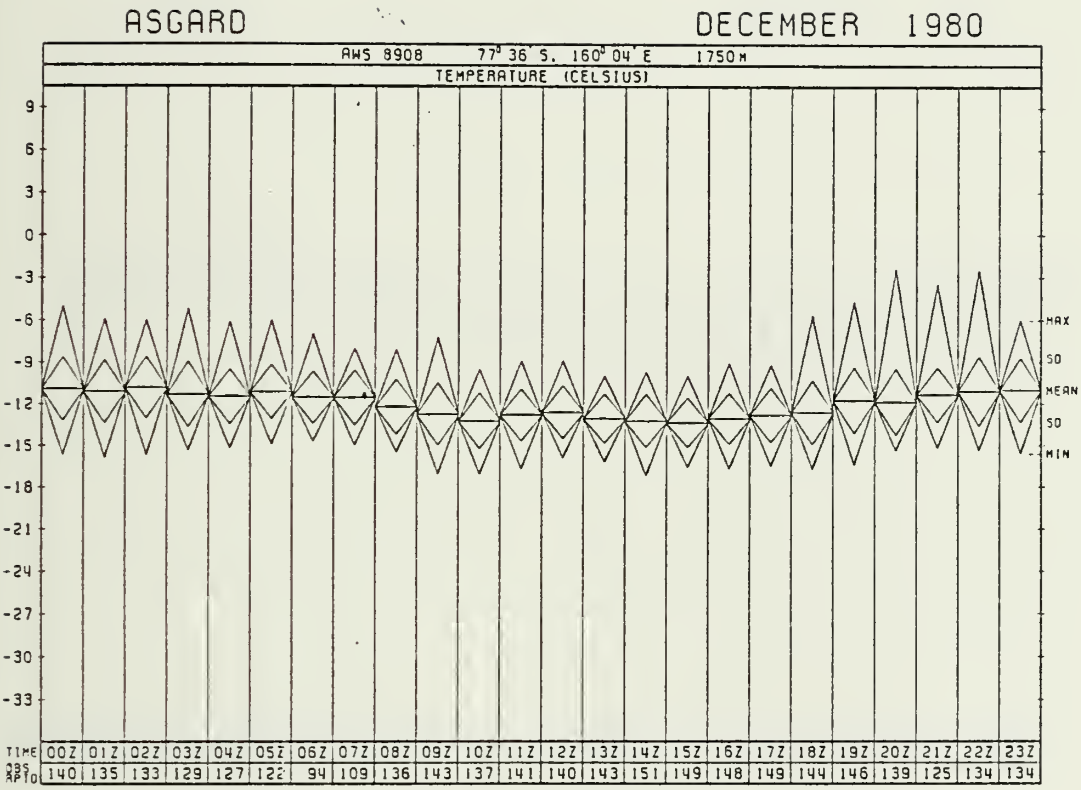


Figure 83. Diurnal Surface Temperature, Asgard, December 1980

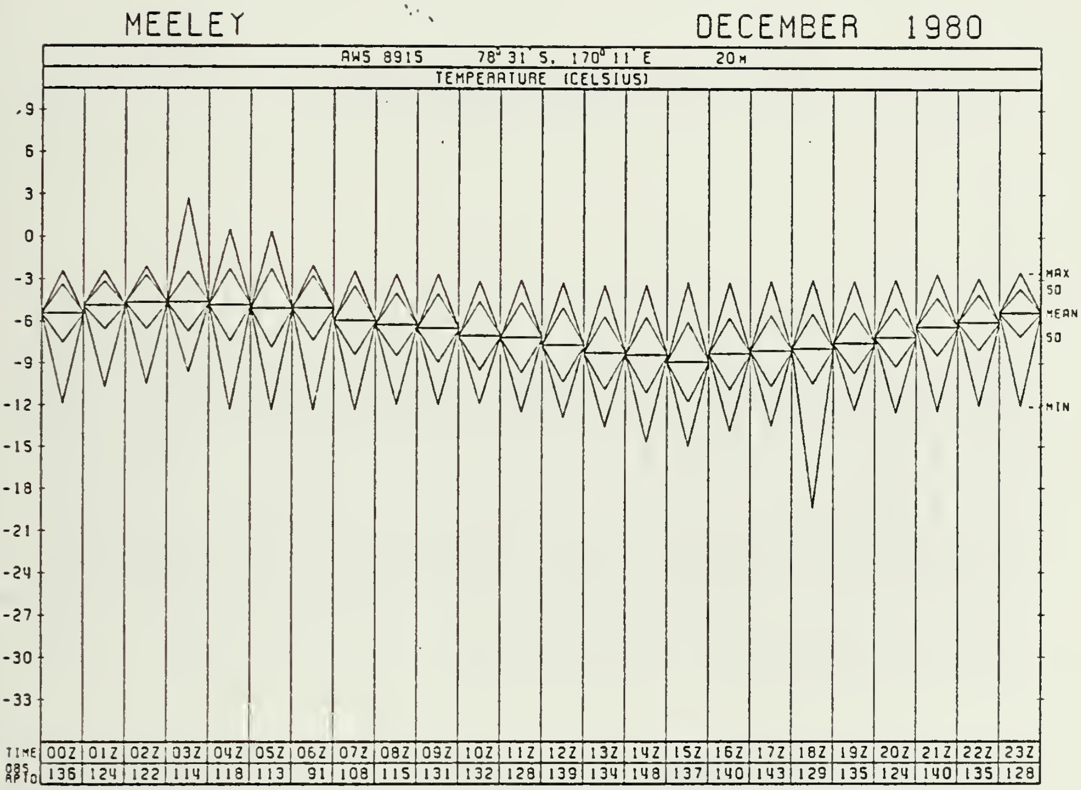


Figure 84. Diurnal Surface Temperature, Meeley, December 1980

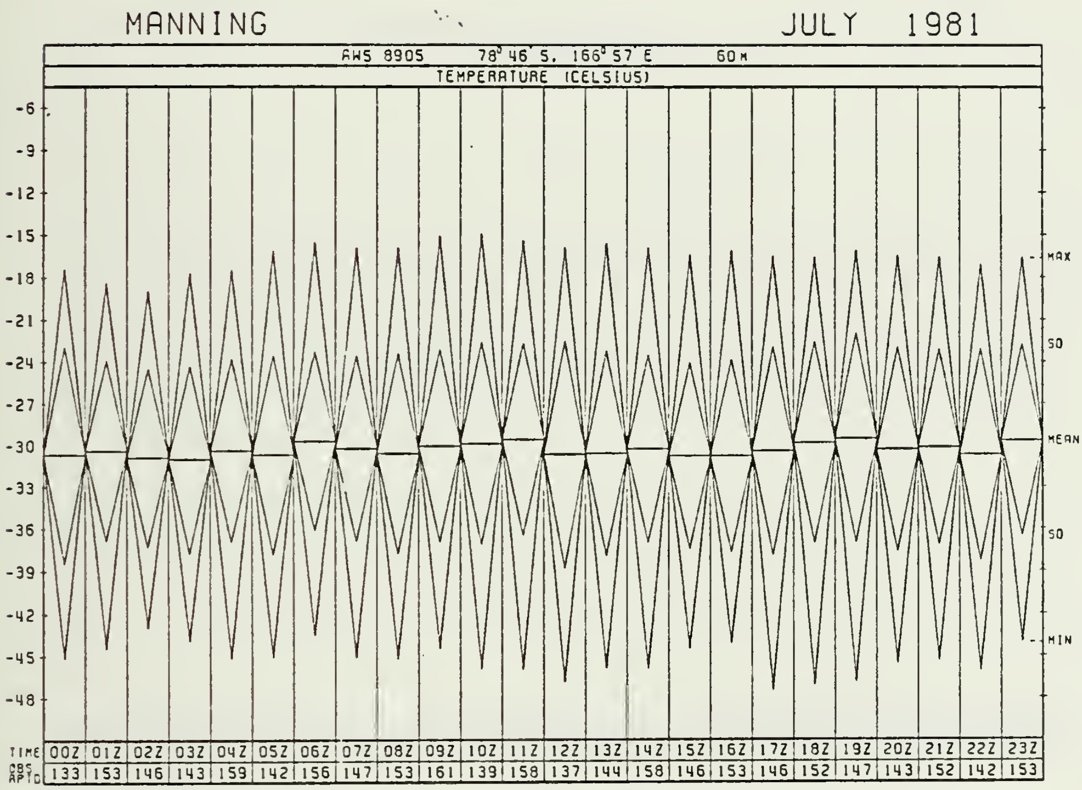


Figure 85. Diurnal Surface Temperature, Manning July 1981

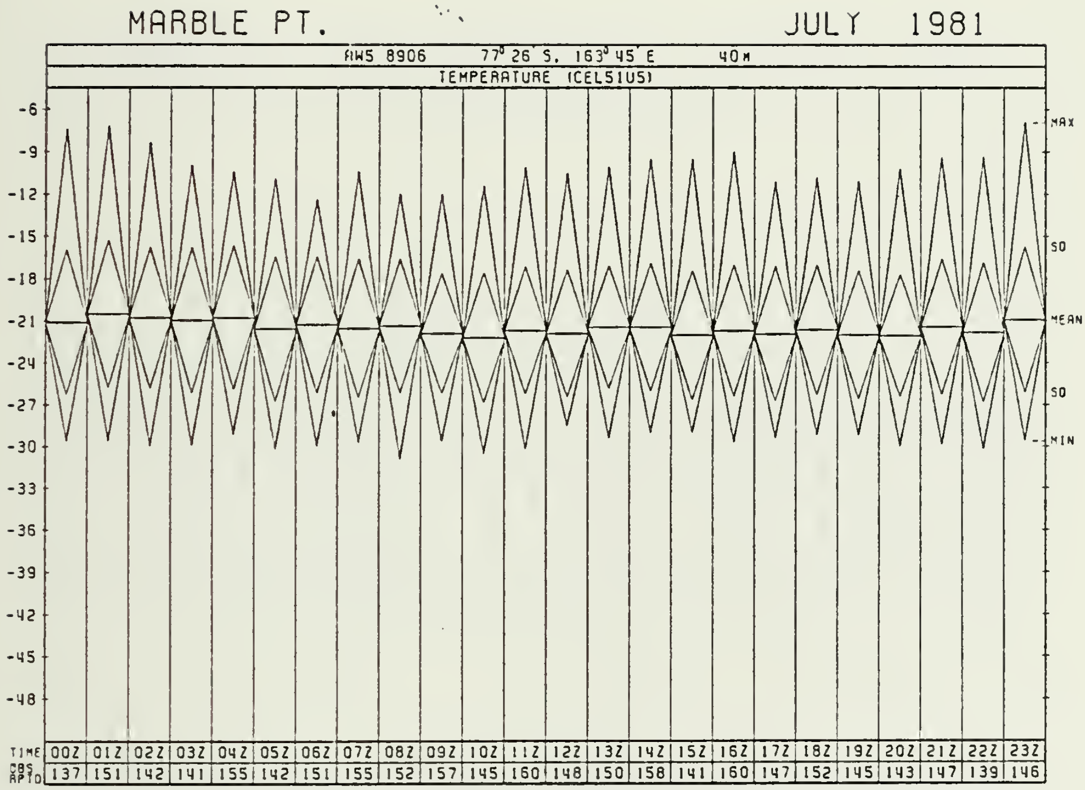


Figure 86. Diurnal Surface Temperature, Marble Point, July 1981

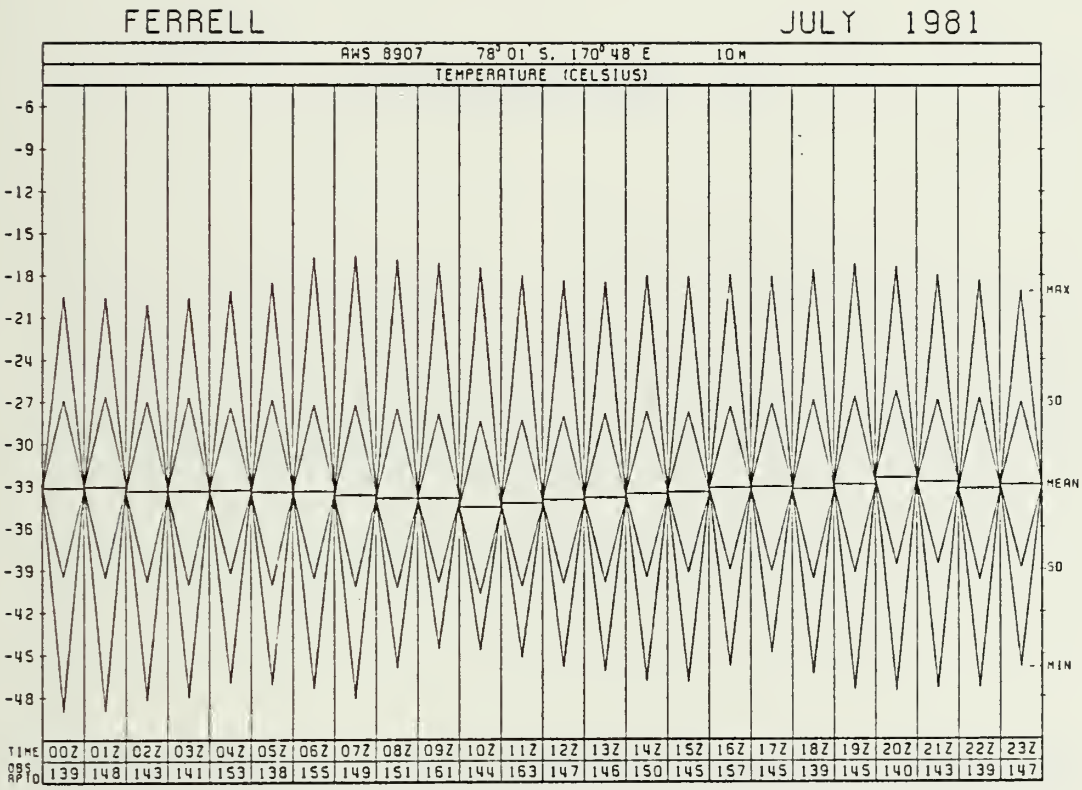


Figure 87. Diurnal Surface Temperature, Ferrell, July 1981

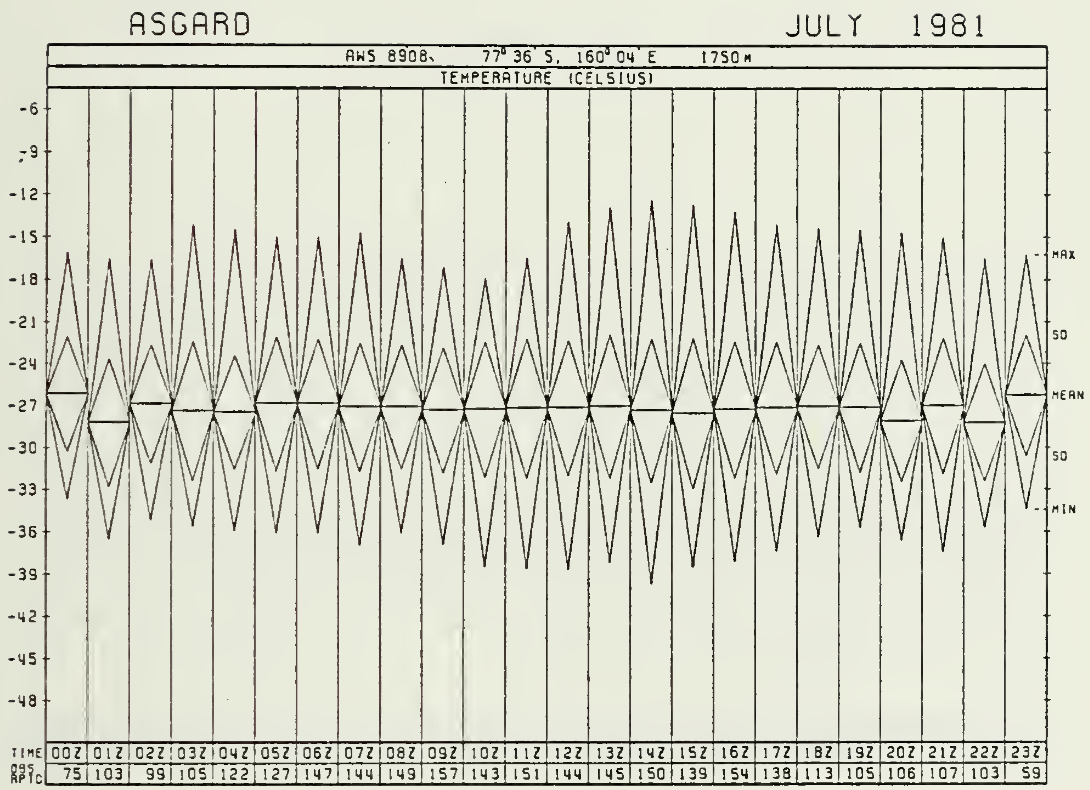


Figure 88. Diurnal Surface Temperature, Asgard, July 1981

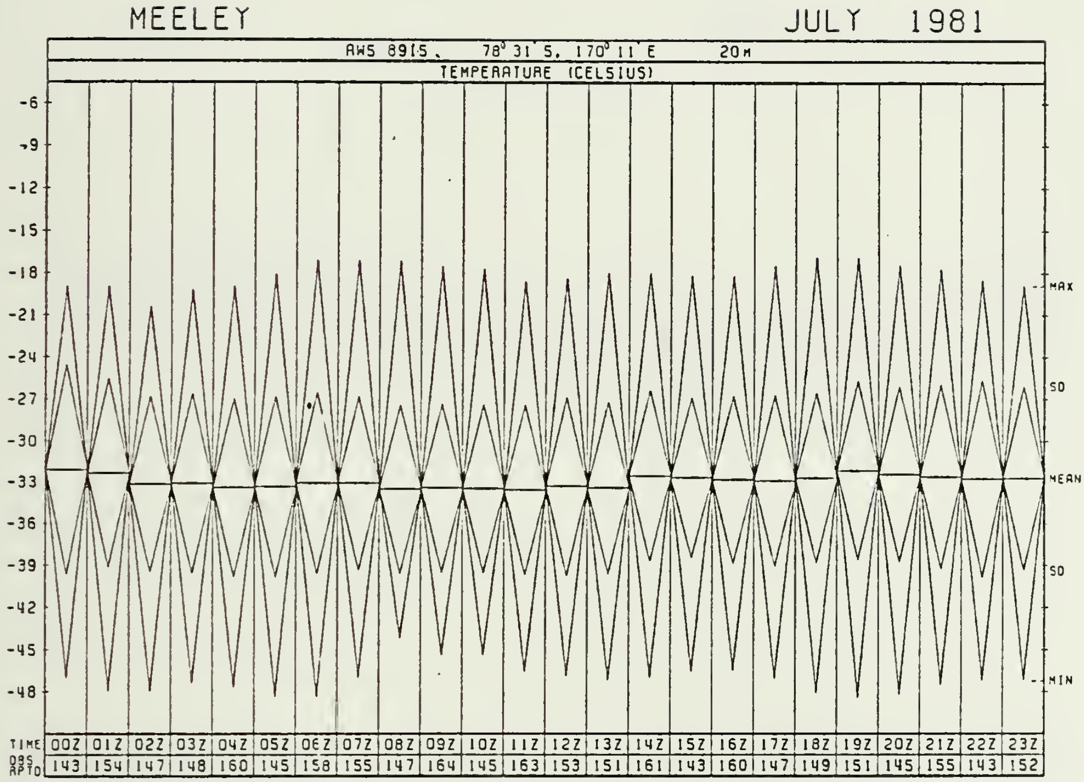


Figure 89. Diurnal Surface Temperature, Meeley, July 1981

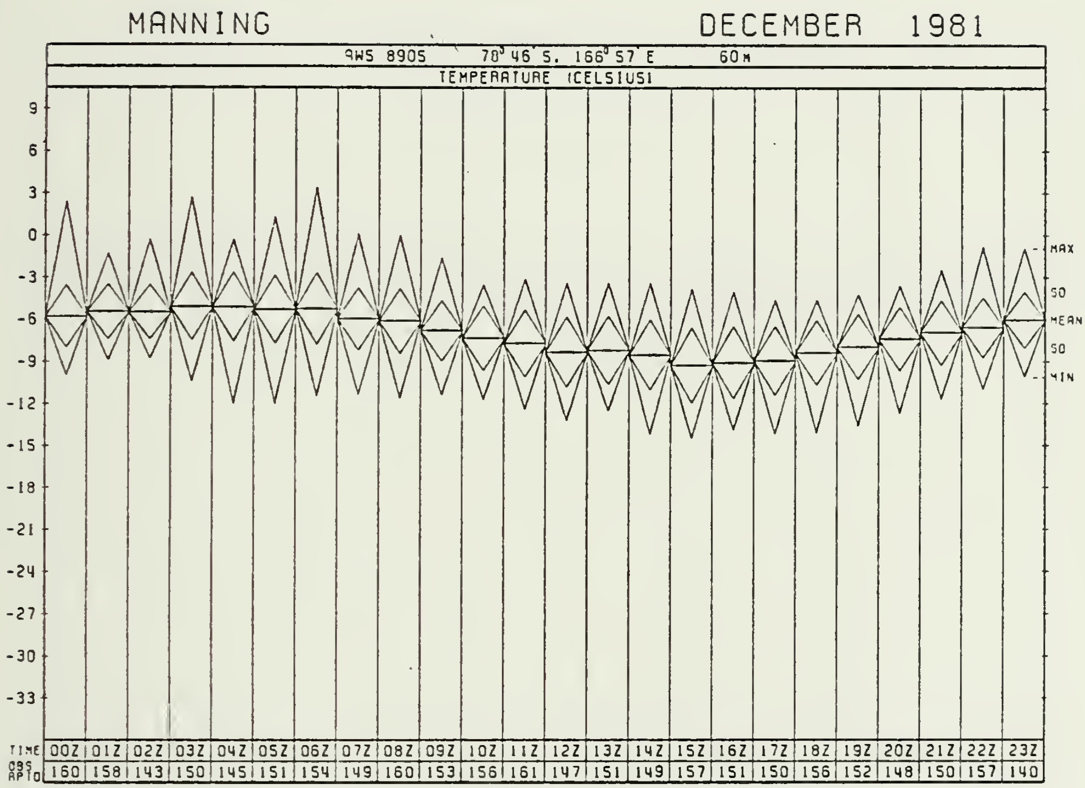


Figure 90. Diurnal Surface Temperature, Manning, December 1981

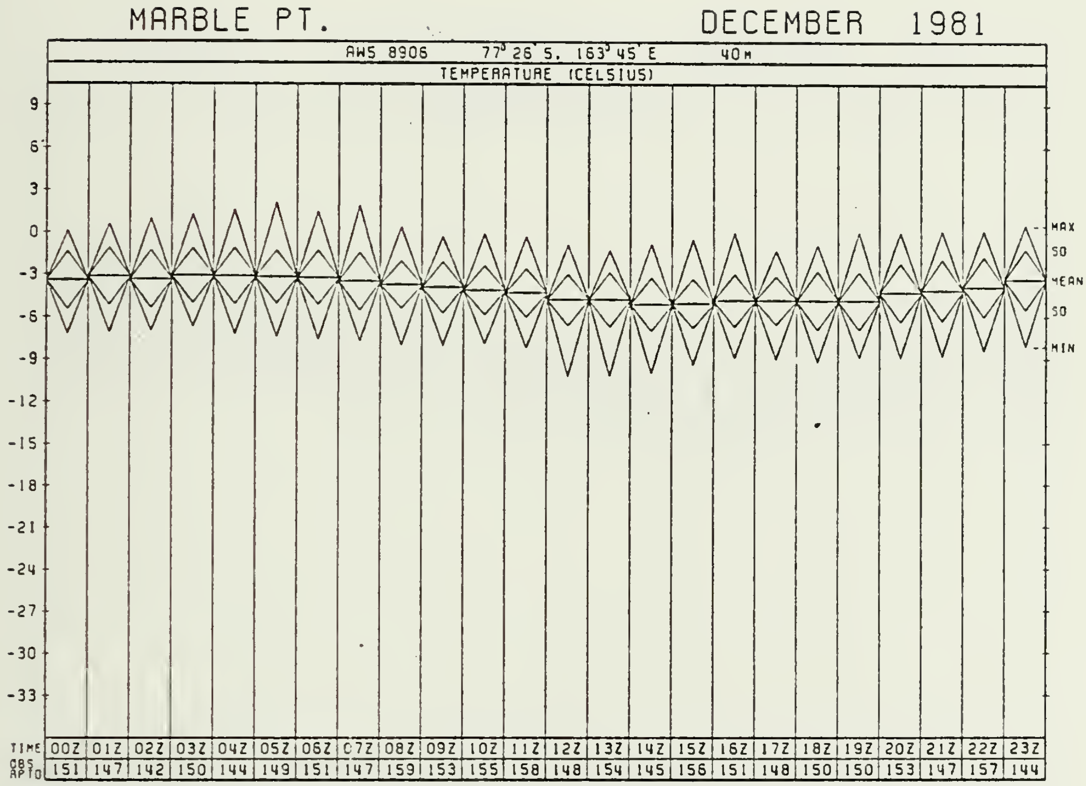


Figure 91. Diurnal Surface Temperature, Marble Point, December 1981

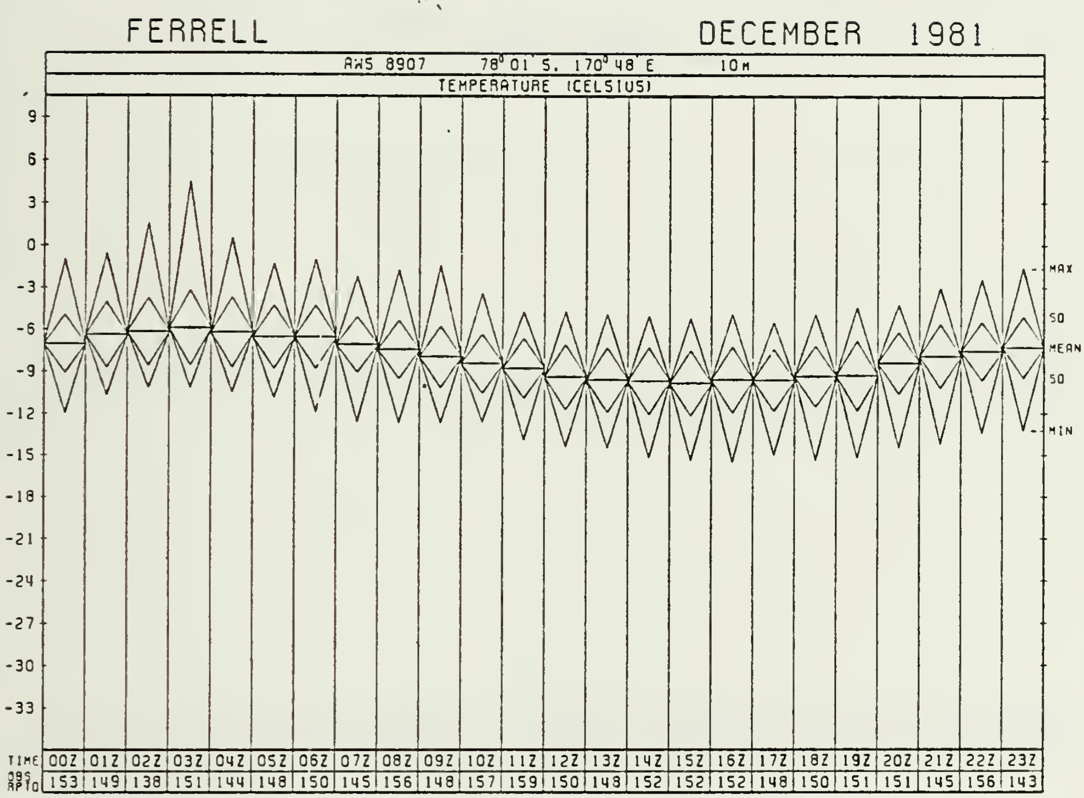


Figure 92. Diurnal Surface Temperature, Ferrell, December 1981

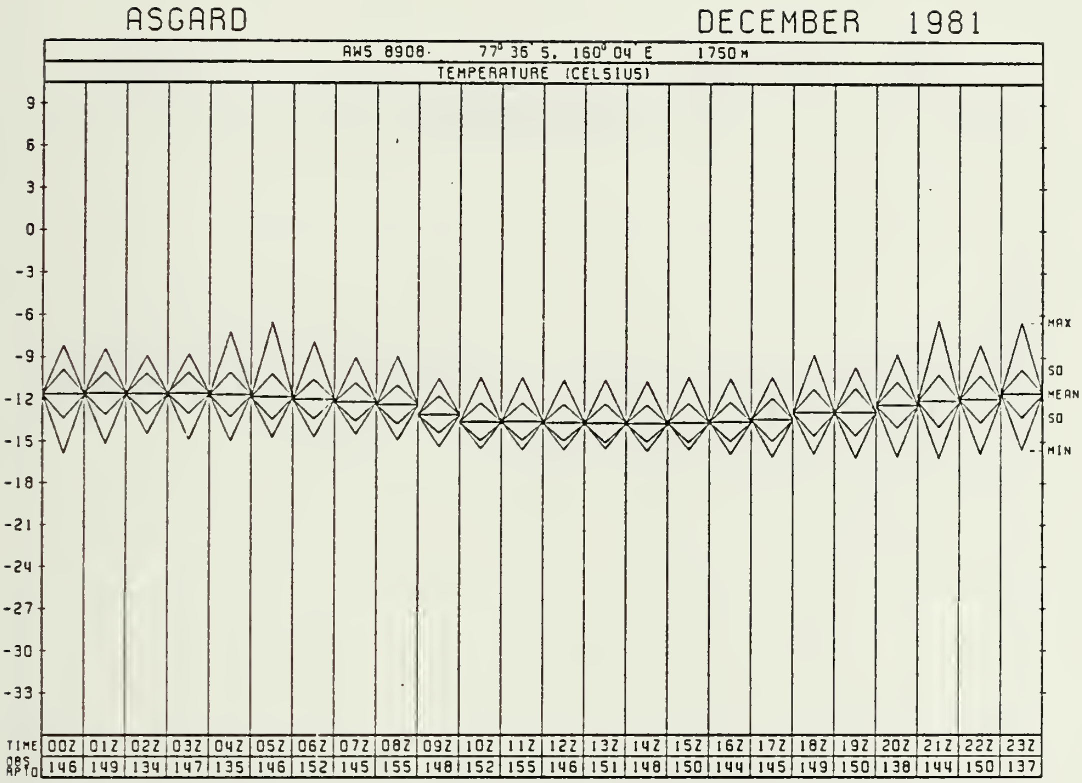


Figure 93. Diurnal Surface Temperature, Asgard, December 1981

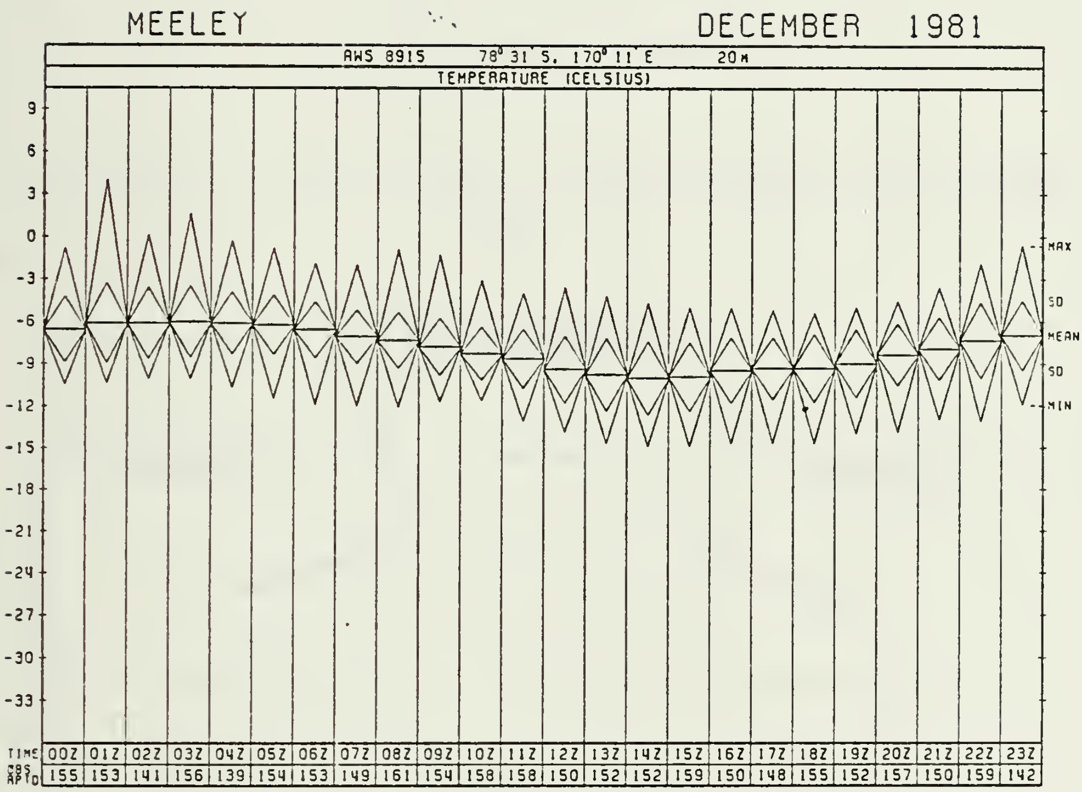
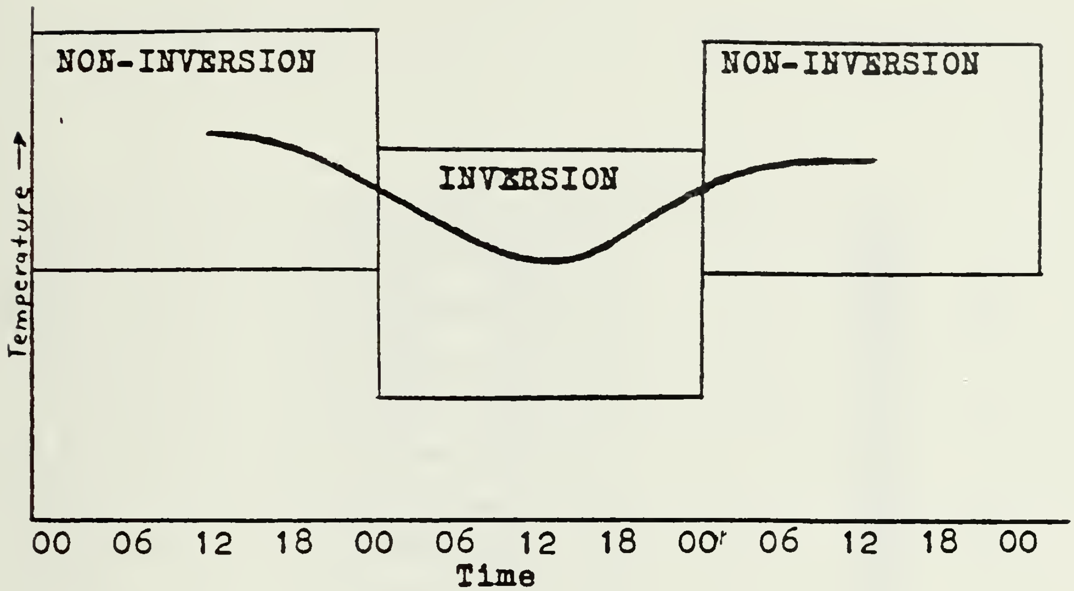


Figure 94. Diurnal Surface Temperature, Meeley, December 1981



(b)

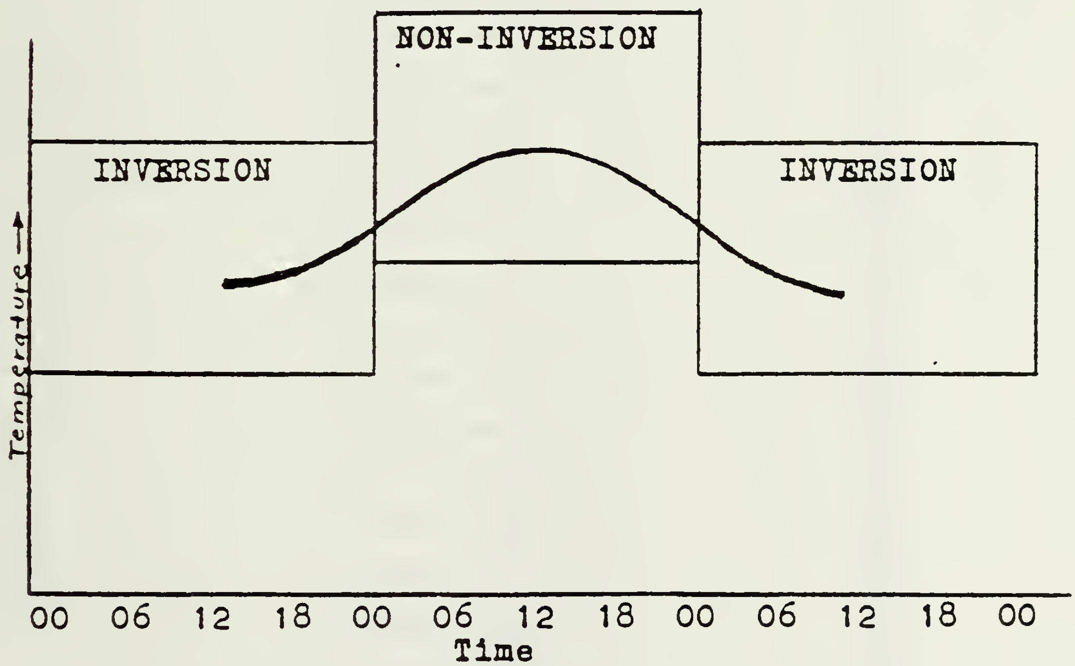


Figure 95. Surface Temperature Bias, South Pole (Hisdal, 1960)

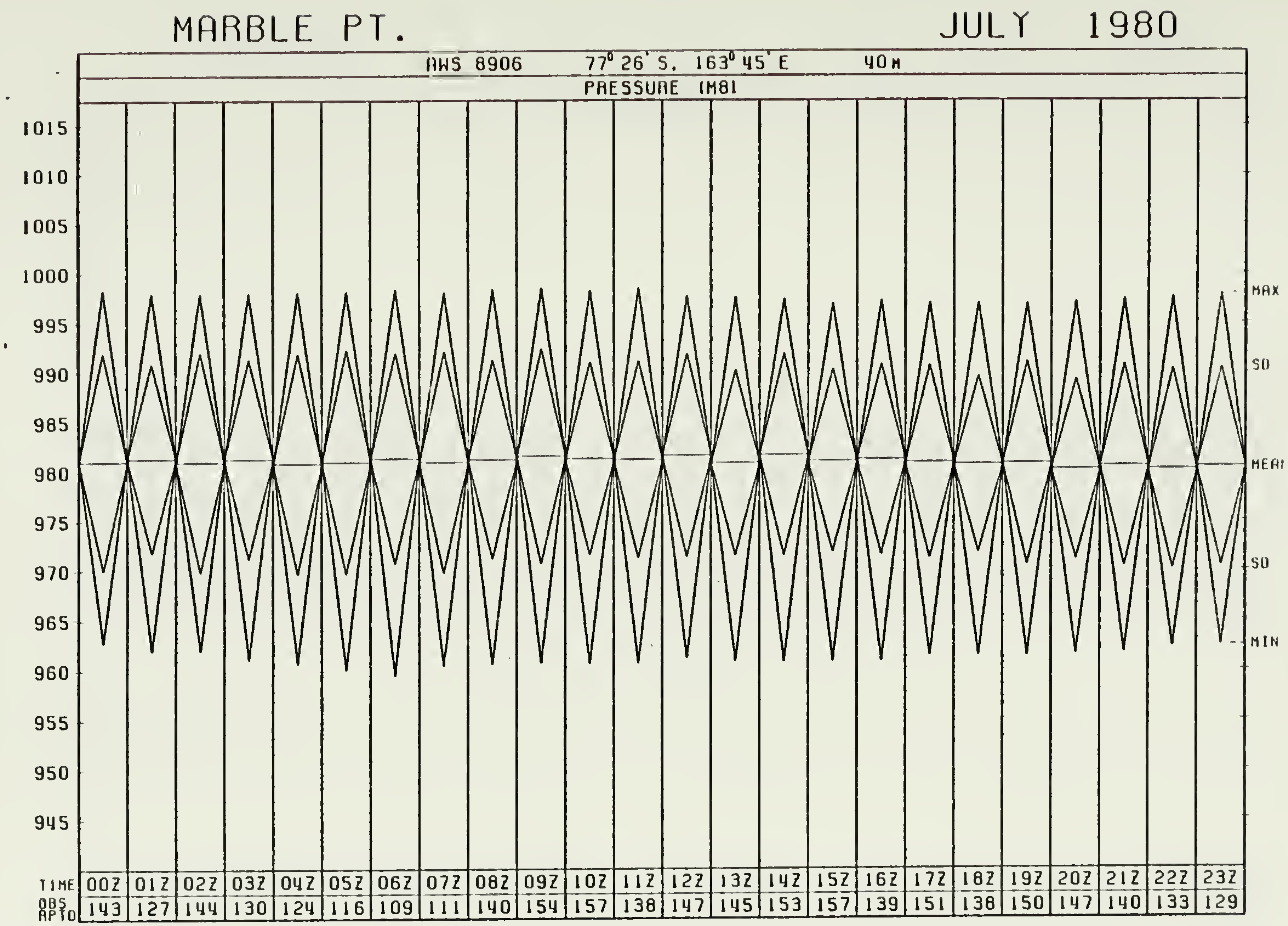


Figure 96. Diurnal Surface Pressure, Marble Point, July 1980

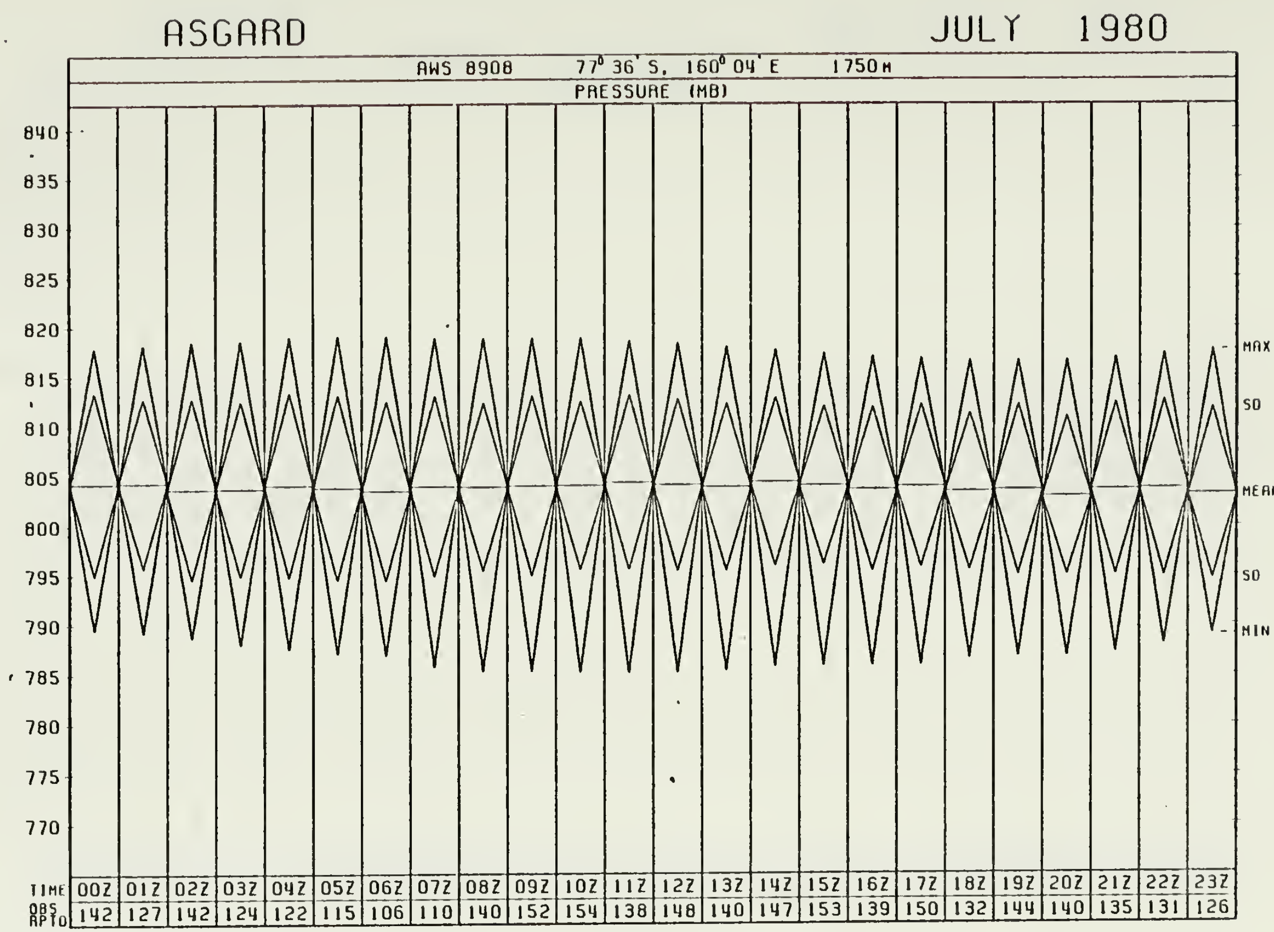


Figure 97. Diurnal Surface Pressure, Asgard, July 1980

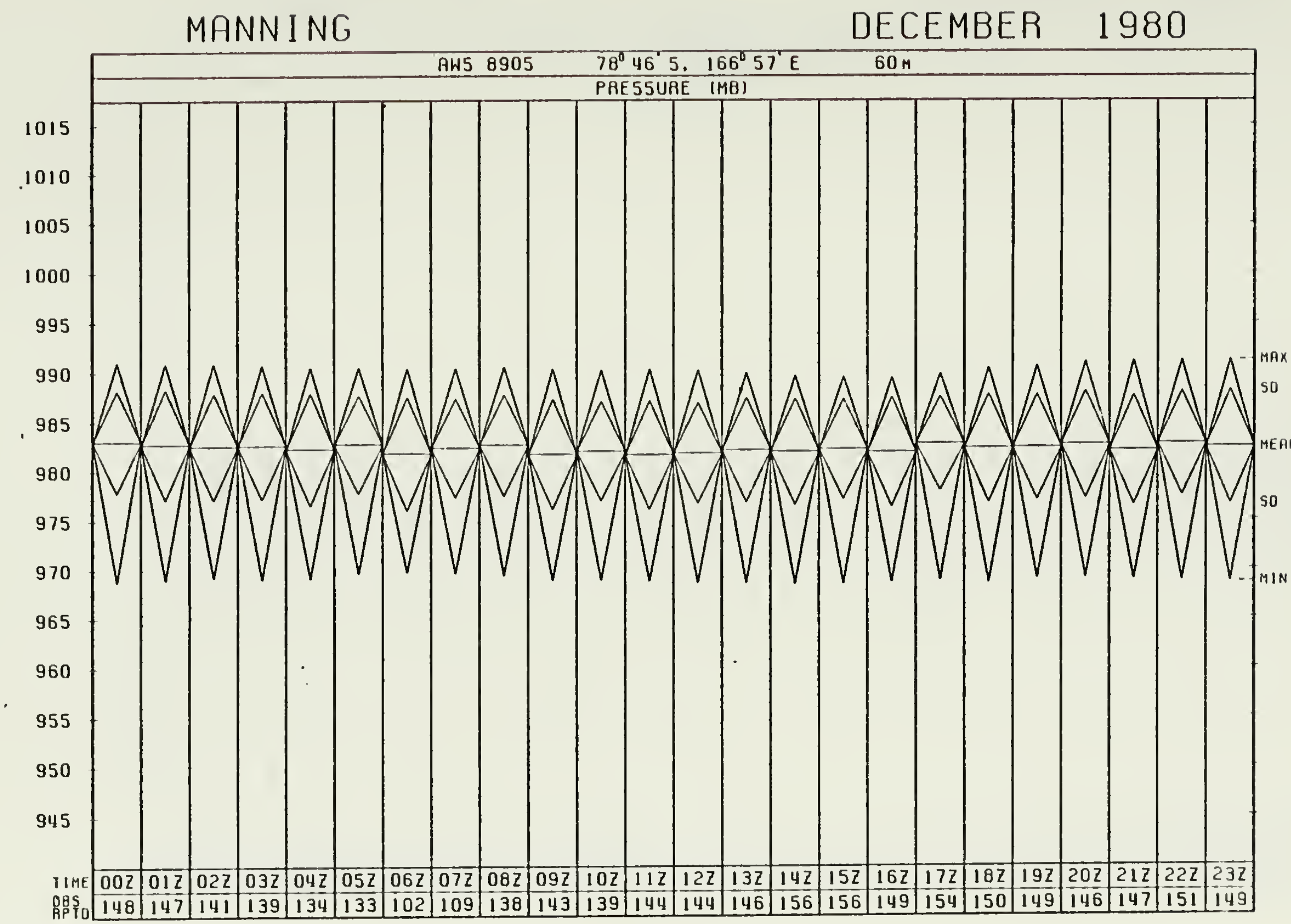


Figure 98. Diurnal Surface Pressure, Manning, December 1980

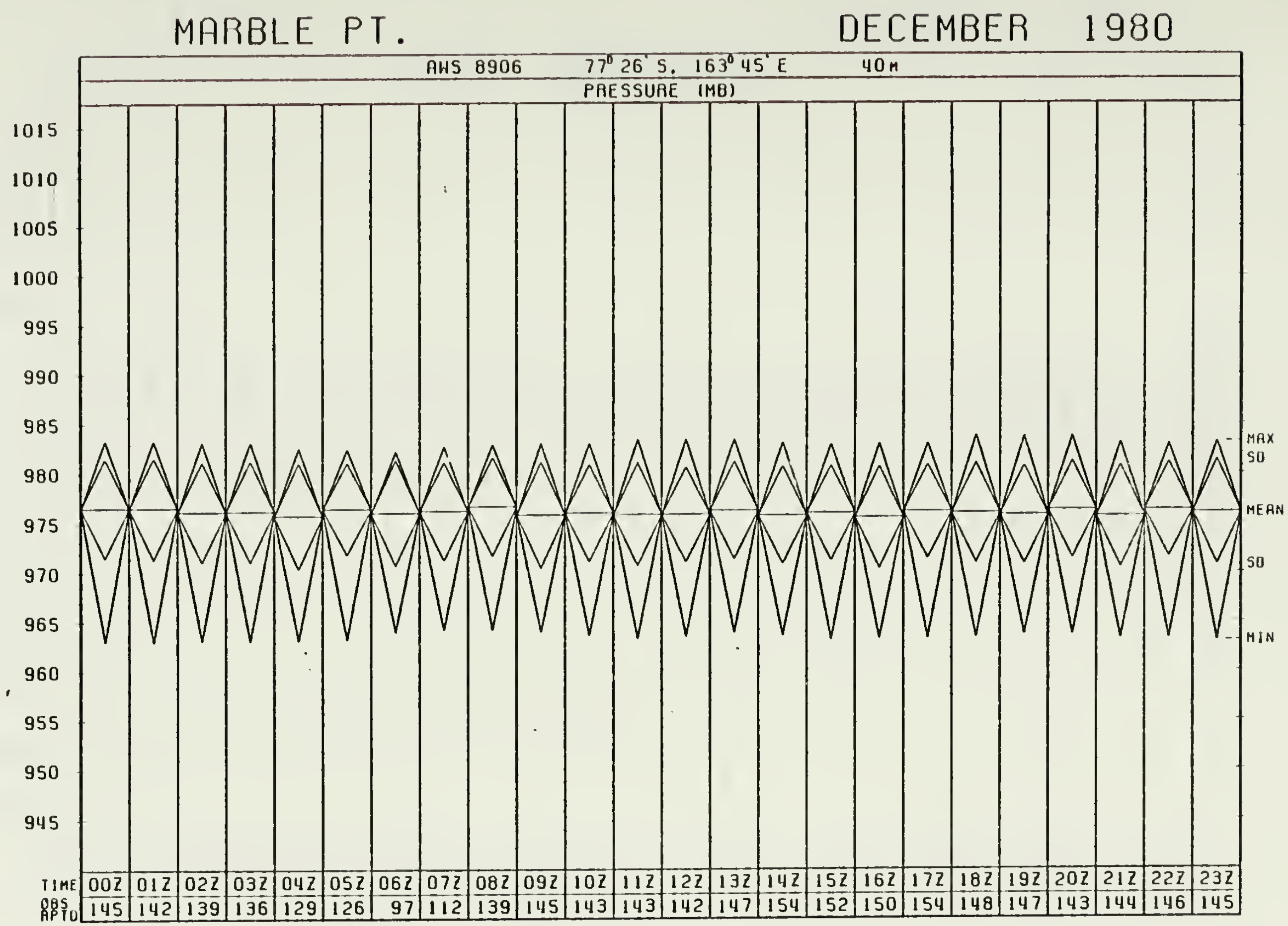


Figure 99. Diurnal Surface Pressure, Marble Point, December 1980

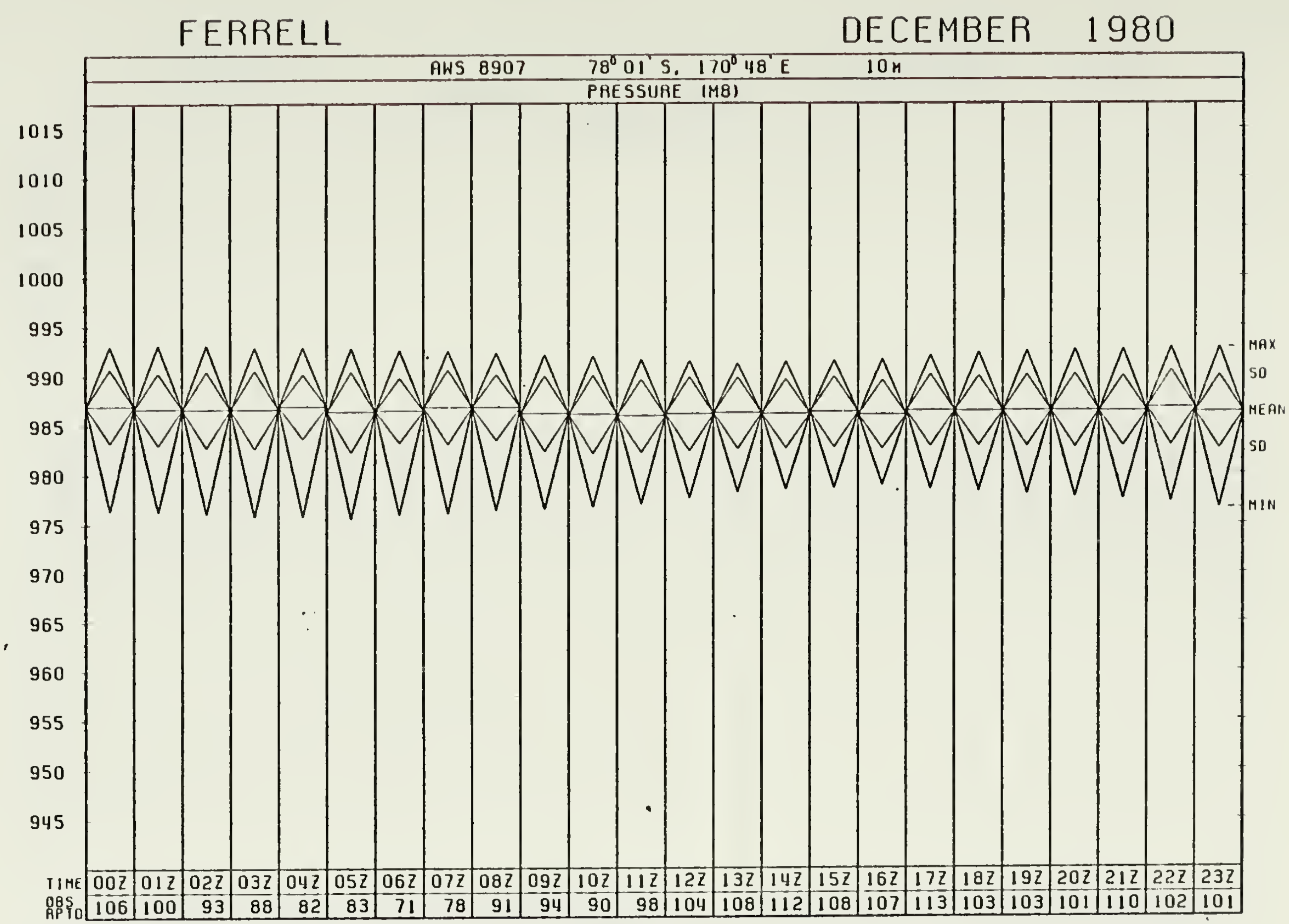


Figure 100. Diurnal Surface Pressure, Ferrell, December 1980

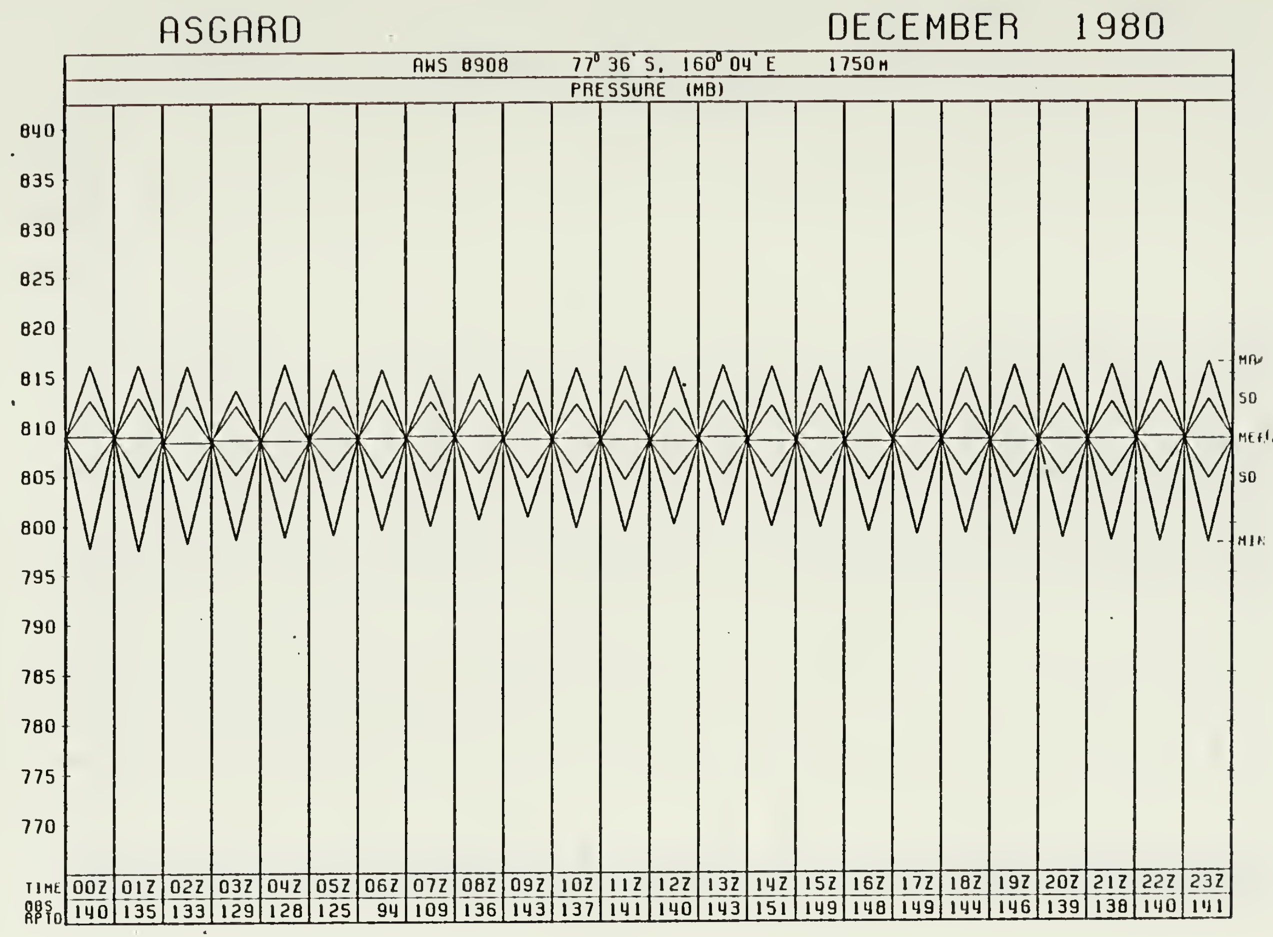


Figure 101. Diurnal Surface Pressure, Asgard, December 1980

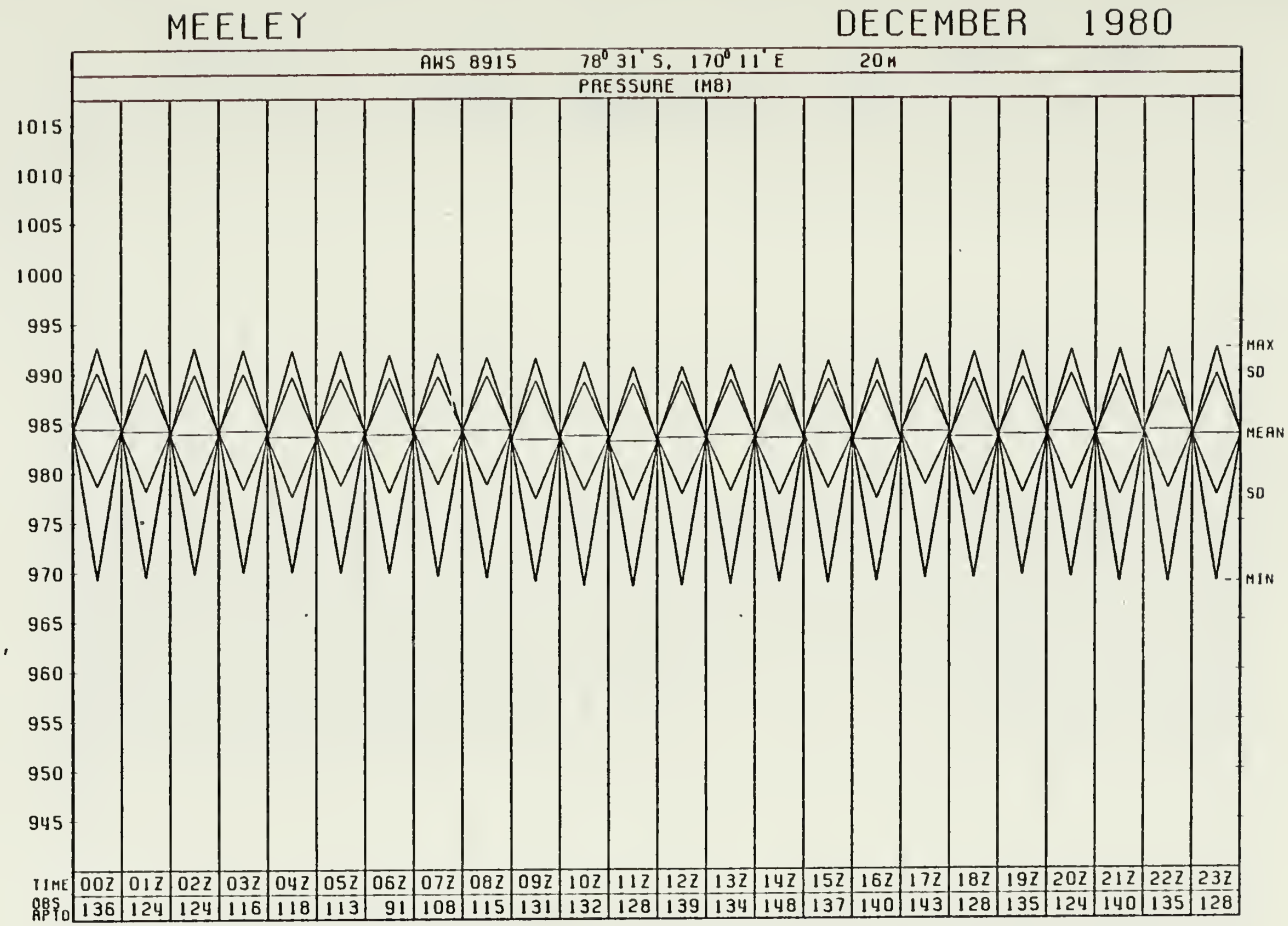


Figure 102. Diurnal Surface Pressure, Meeley, December 1980

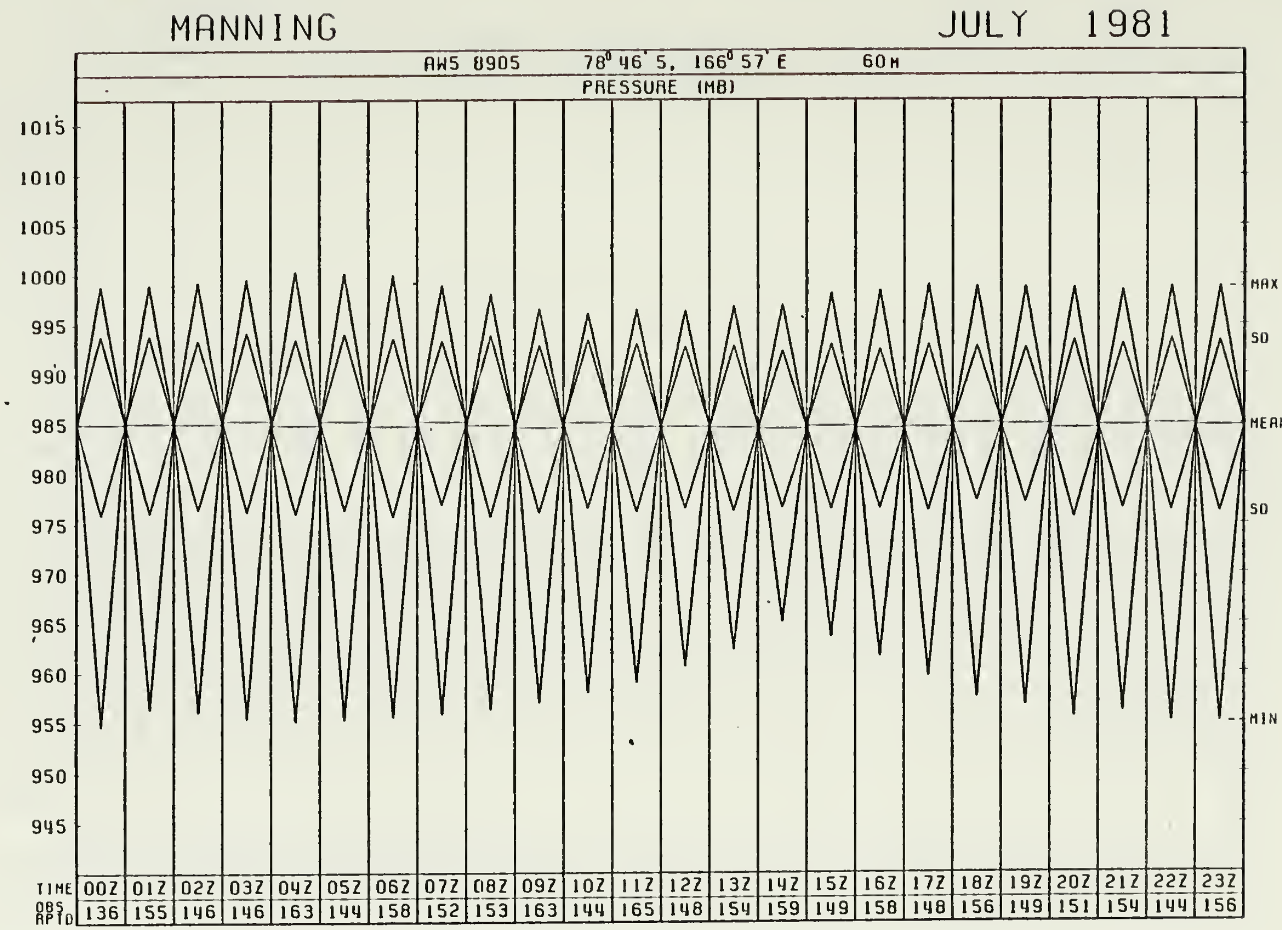


Figure 103. Diurnal Surface Pressure, Manning, July 1981

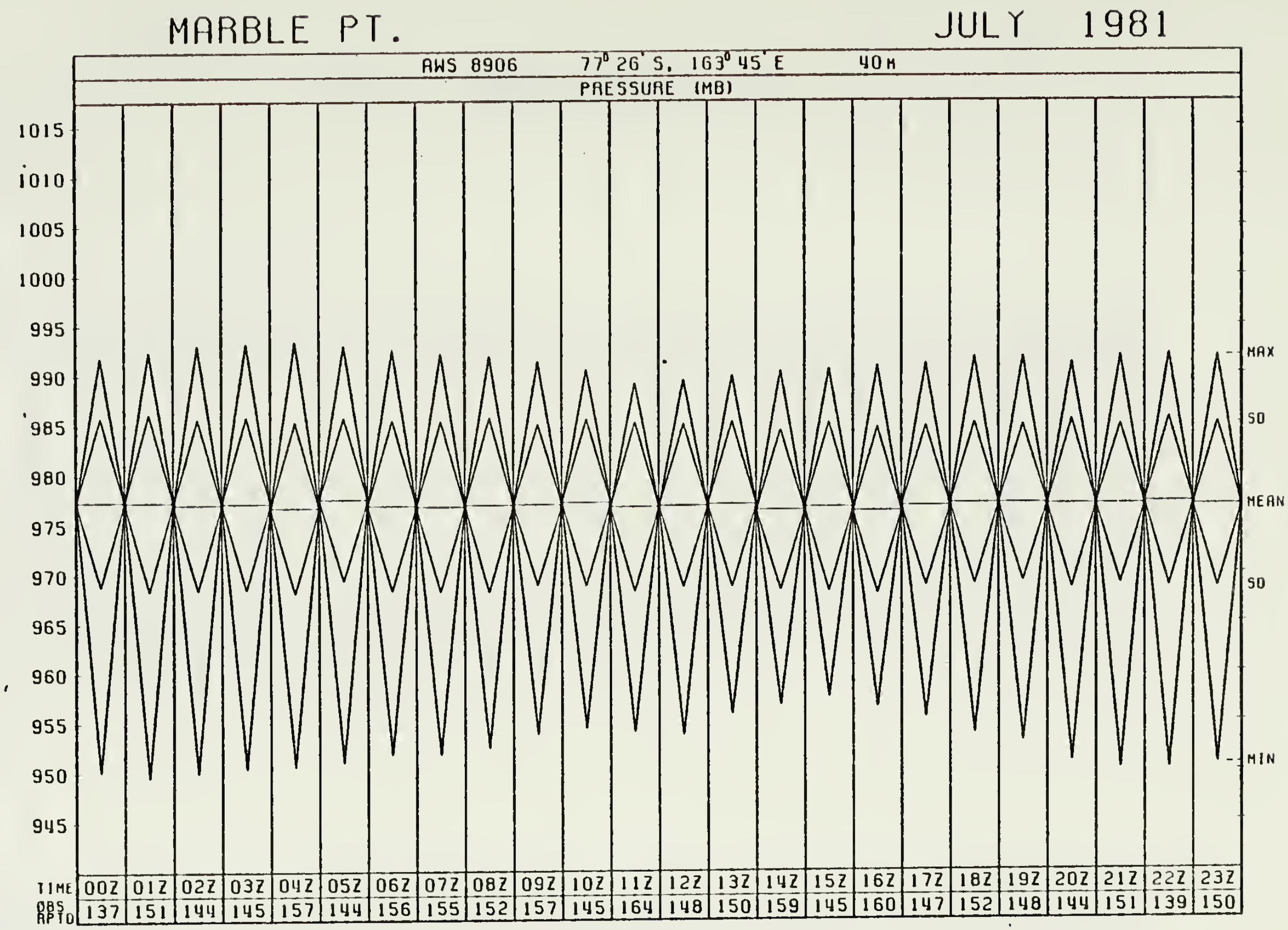


Figure 104. Diurnal Surface Pressure, Marble Point, July 1981

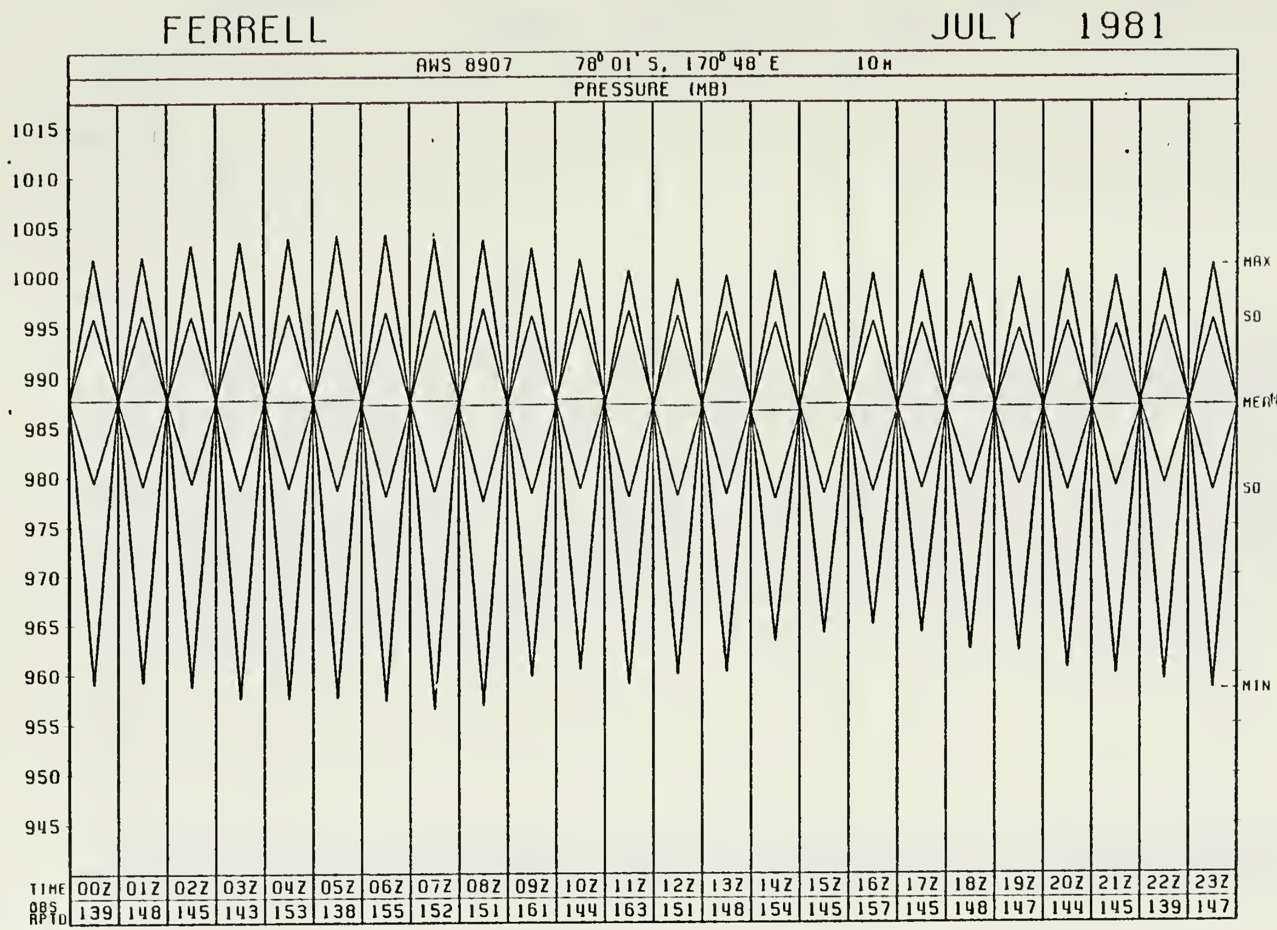


Figure 105. Diurnal Surface Pressure, Ferrell, July 1981

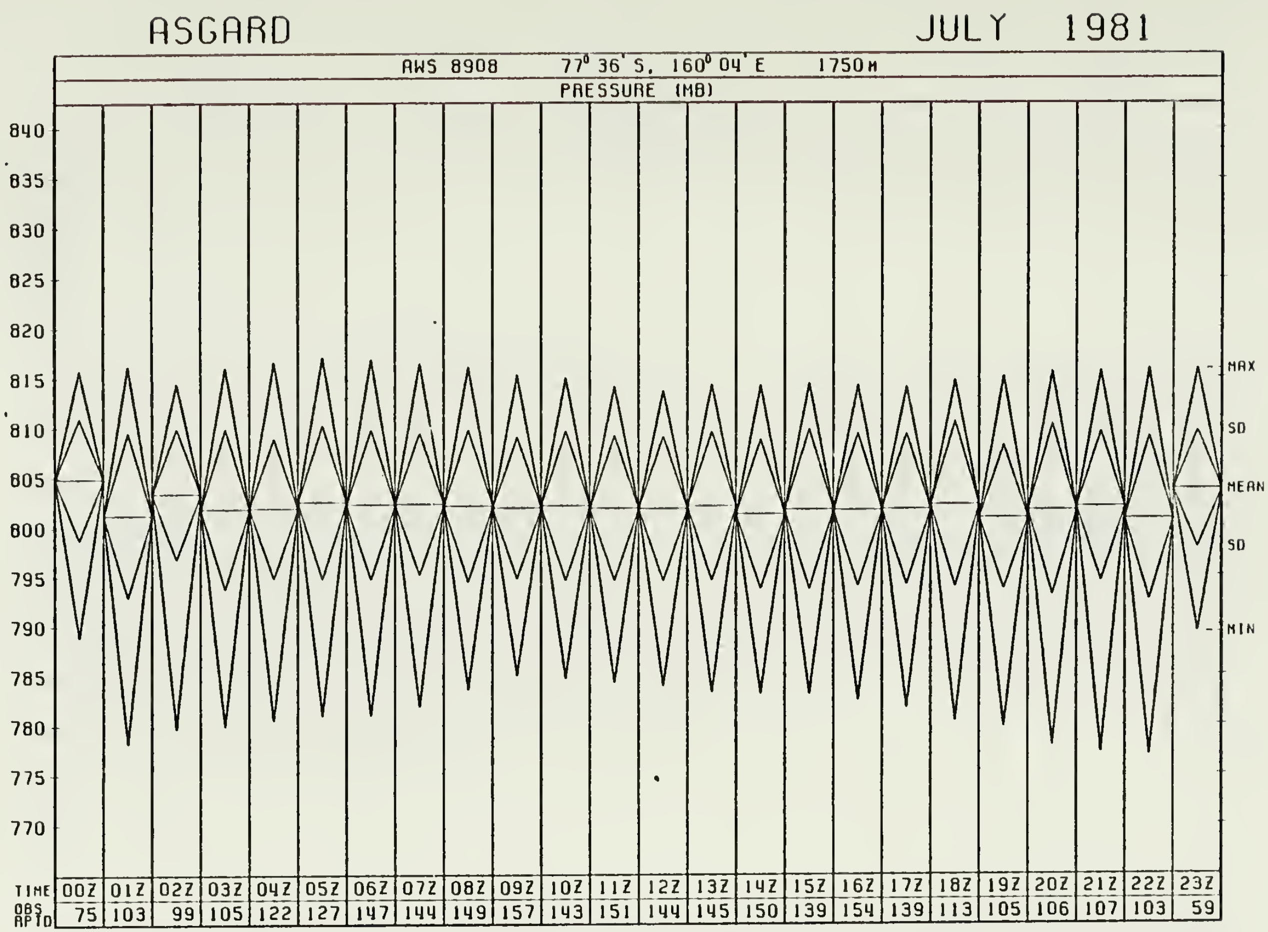


Figure 106. Diurnal Surface Pressure, Asgard, July 1981

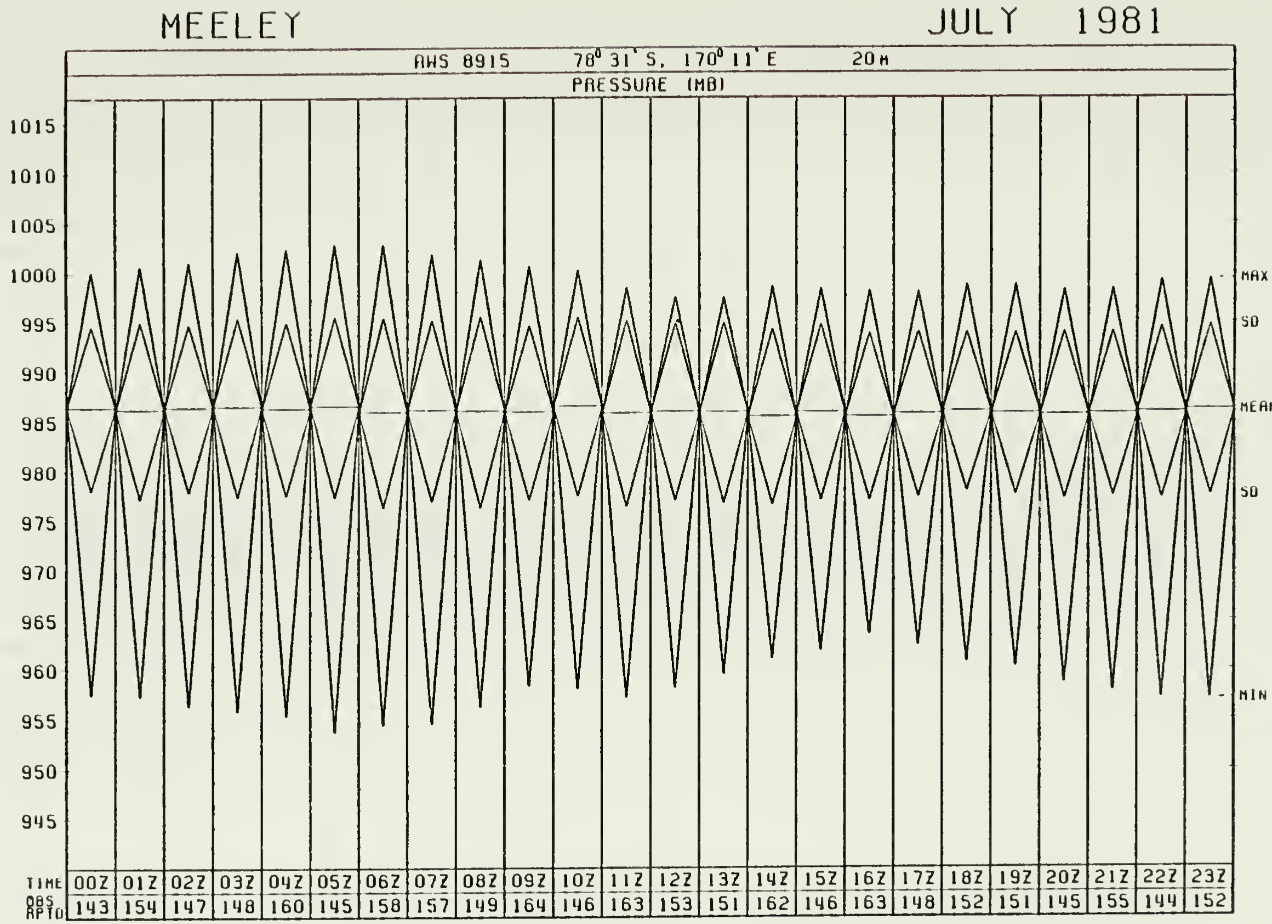


Figure 107. Diurnal Surface Pressure, Meeley, July 1981

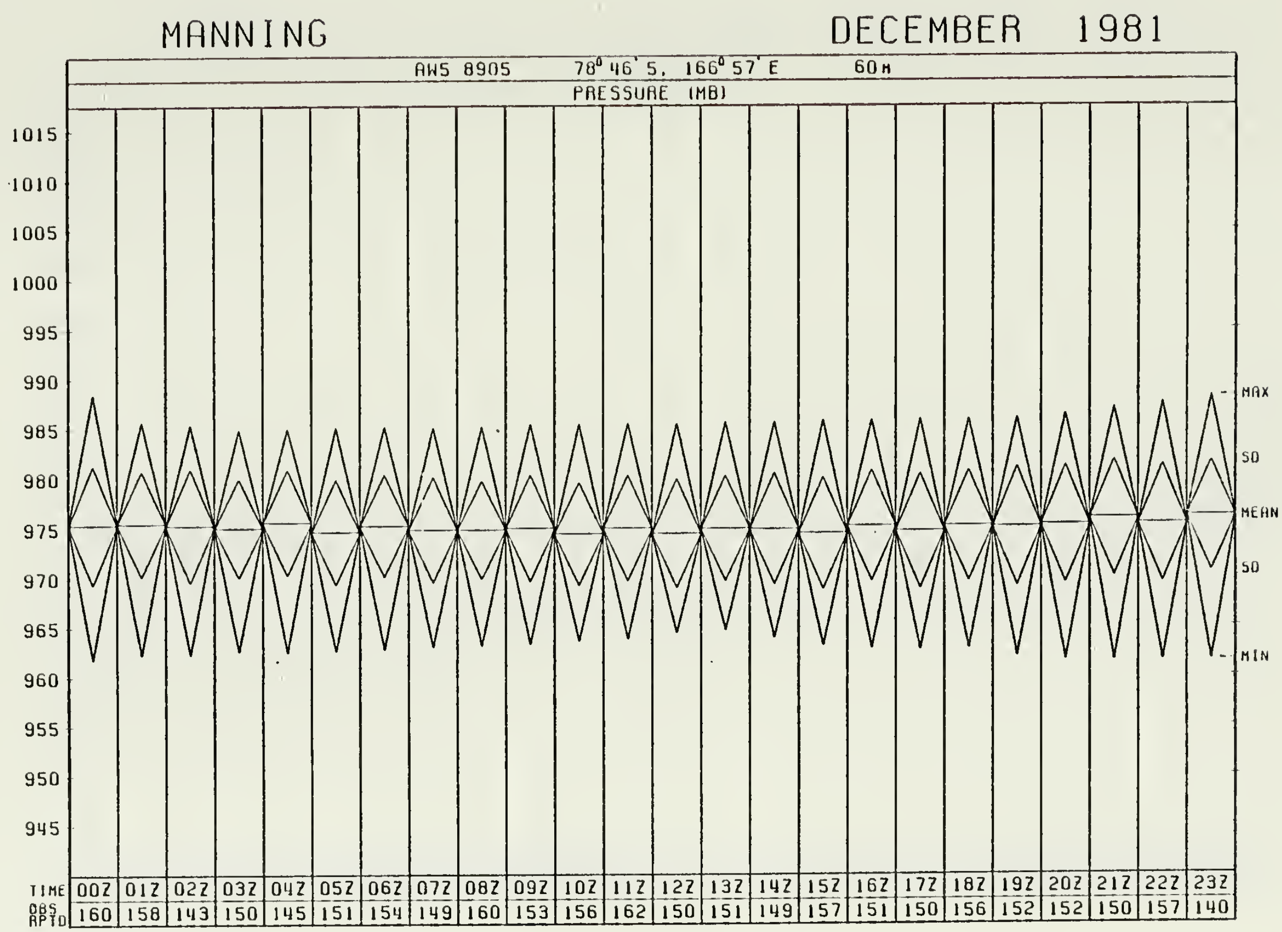


Figure 108. Diurnal Surface Pressure, Manning, December 1981

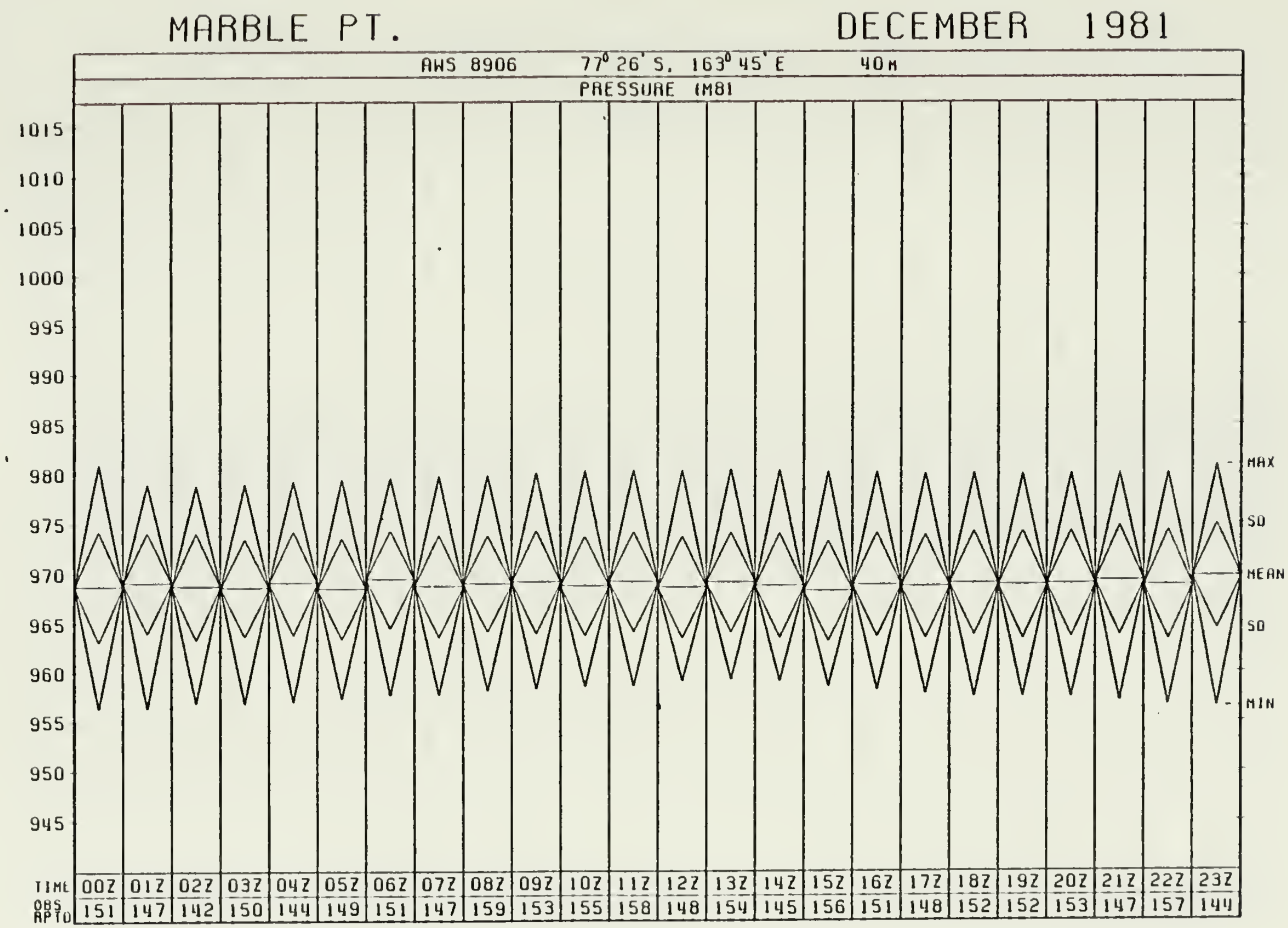


Figure 109. Diurnal Surface Pressure, Marble Point, December 1981

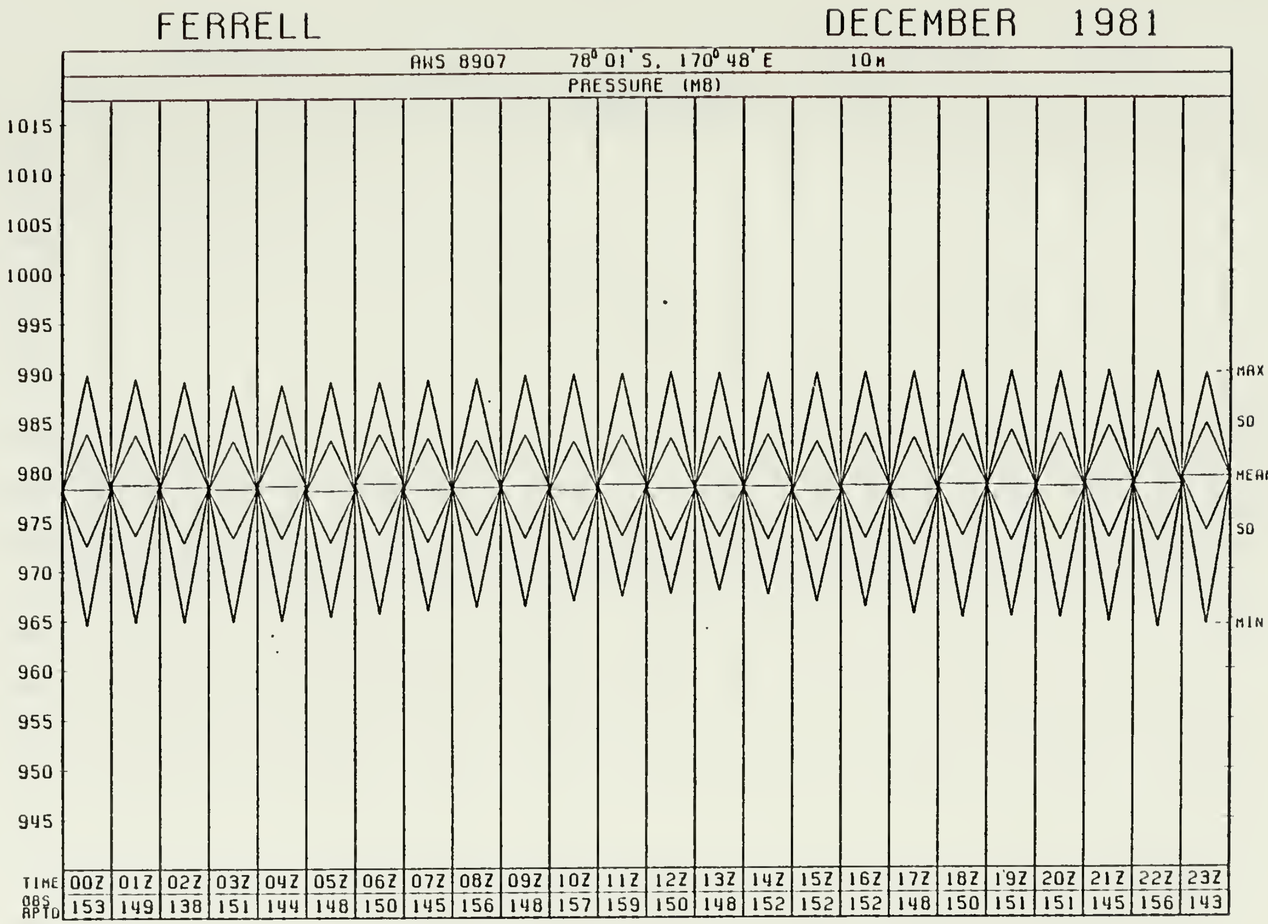


Figure 110. Diurnal Surface Pressure, Ferrell, December 1981

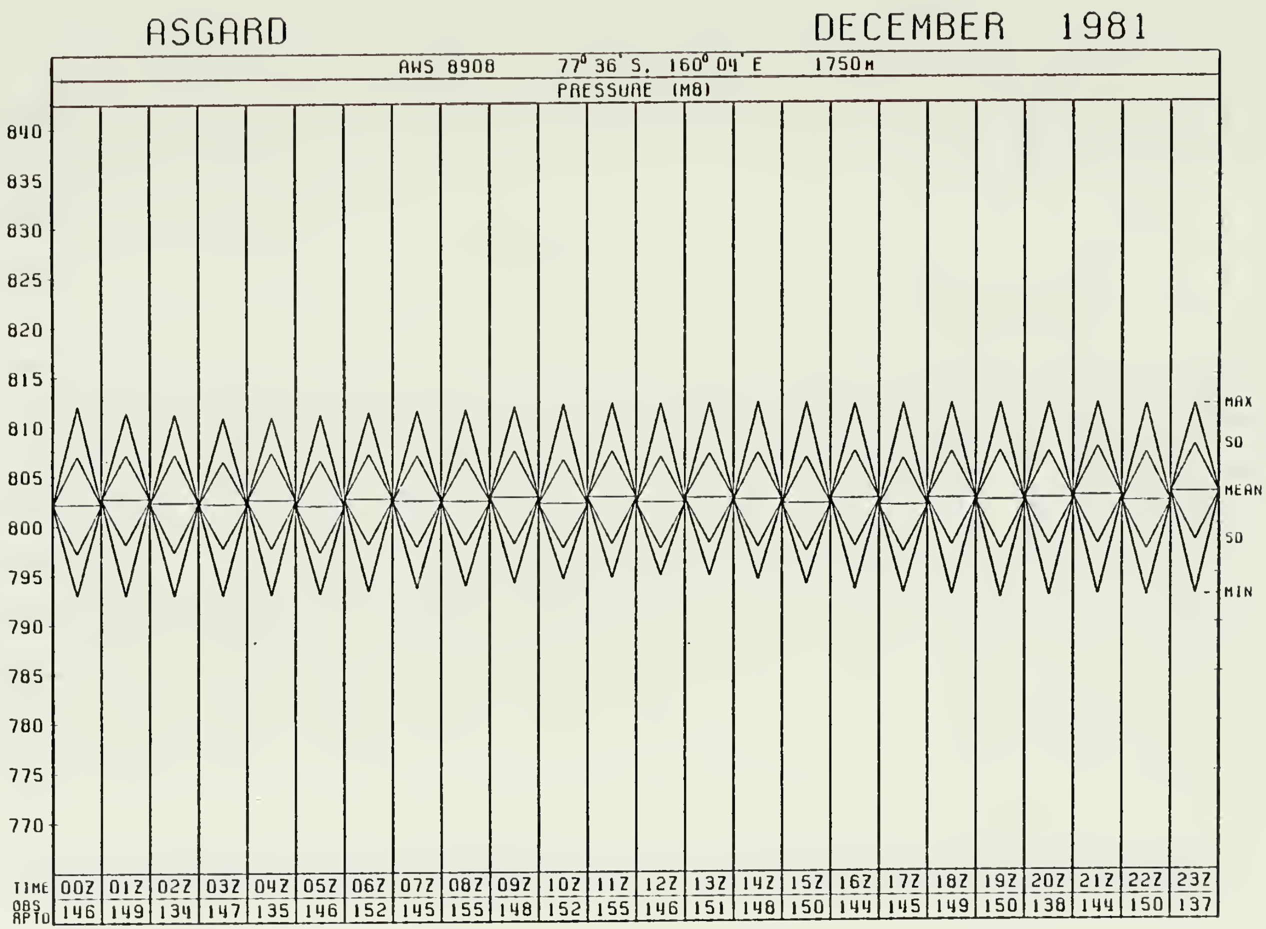


Figure 111. Diurnal Surface Pressure, Asgard, December 1981

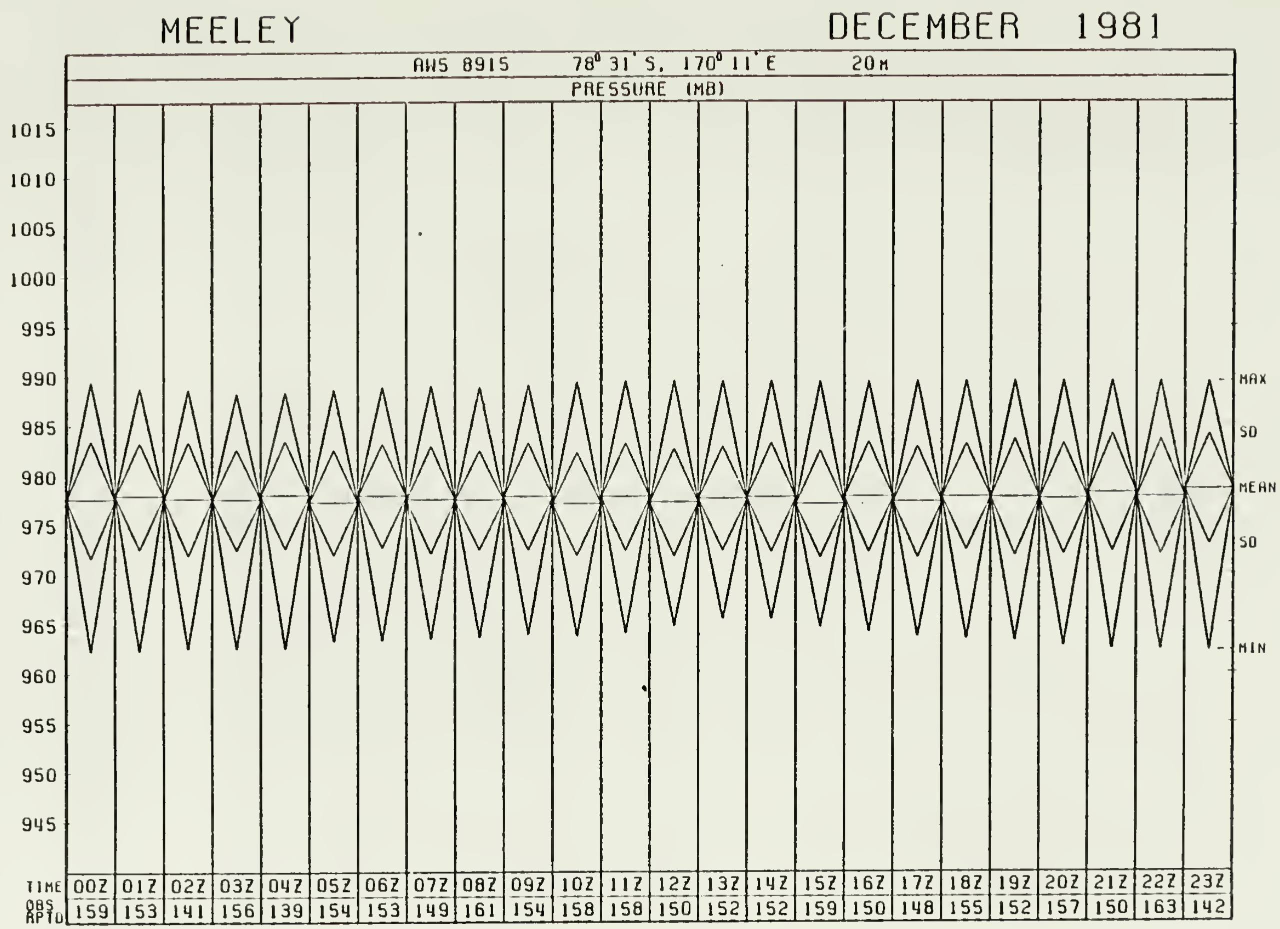


Figure 112. Diurnal Surface Pressure, Meeley, December 1981

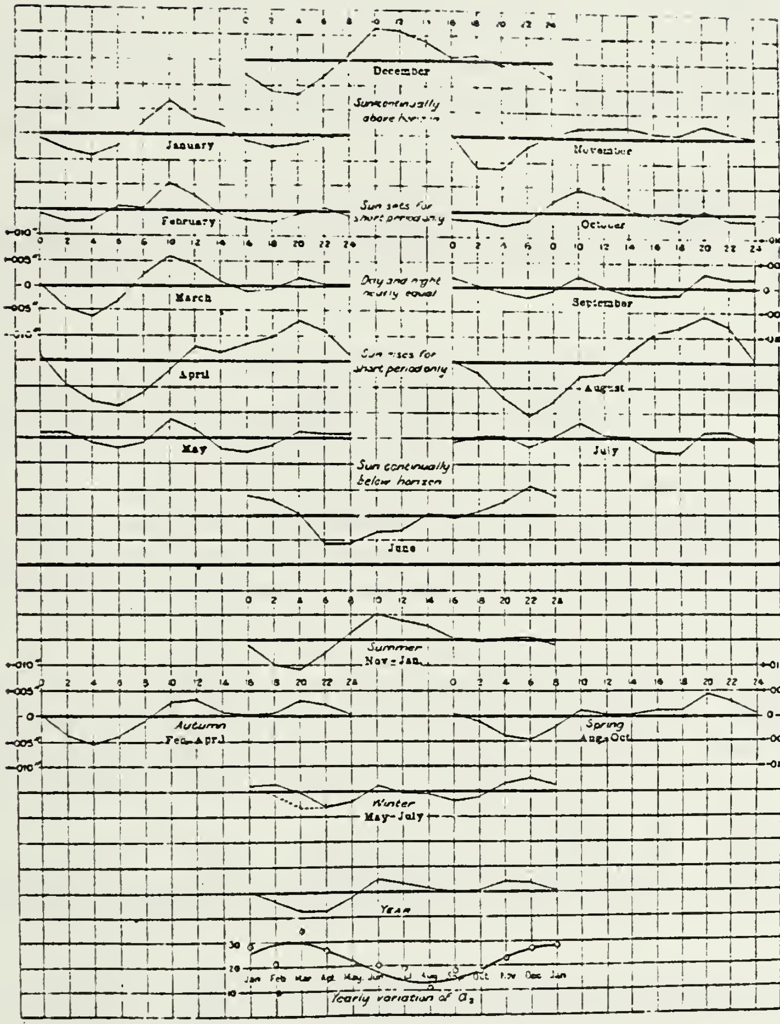


Figure 113. Annual and Monthly Diurnal Variation of Surface Pressure, McMurdo (Simpson, 1919)

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